MINERAL STATUS OF BRAHMAN BEEF CATTLE RECEIVING MINERAL SUPPLEMENTATION IN CENTRAL FLORIDA

By

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1984

To my wife, Iftikar, for her help

and her continued encouragement

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation and special gratitude to Dr. L.R. McDowell for his guidance, direction and encouragement in the preparation and supervision of this dissertation. Special appreciation is also extended to Drs. J.F. Hentges, Jr., and R.M. Mason for their advice and help with the experimental procedure at Pine Acres Beef Research Farm.

The author is very grateful and truly thankful to Dr. C.J. Wilcox for his advice and aid in the experimental design and assistance with statistical analysis. Much appreciation also extended to Dr. J.H. Conrad, Dr. C.B. Ammerman and Dr. D.C. Rueika for their suggestions, time and advice as members of the supervisory committee.

Deep respect and appreciation are offered to Mrs. Nancy Wilkinson and Mrs. Pamela H. Miles for their assistance and help in the laboratory work. A special note of thanks is extended to Mr. Jerry Wasdin, Manager of the Purebred Beef Unit and his commendable staff for their help and assistance in sample collection and record keeping.

The author is grateful to his wife, Iftikar, for her patience, encouragement and understanding. Thanks are owed to the Central Veterinary Research Laboratory and the Democratic Republic of the Sudan for their financial support.

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Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment
of the Requirements for the Degree of Doctor of Philosophy

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RECEIVING MINERAL SUPPLEMENTATION
IN CENTRAL FLORIDA

By

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April, 1984

Chairman: Dr. L.R. McDowell
Major Department: Animal Science

An experiment was conducted at the University of Florida, Pine Acres Beef Research Farm in central Florida, in the dry and wet seasons. 1) to investigate the mineral status of Brahman beef cattle and effect of mineral supplementation, 2) to evaluate the possibility of a correlation between dams' mineral supplementation and calf blood profiles, vigor, and nursing response, 3) to compile data of blood profile for Brahman calves at birth, at 3 days old, and at 3 months old. Animal tissues, soil, and forage samples were collected 6 times during the experimental period. Minerals were analyzed in samples of soil, forage, and animal tissues (blood, liver, bone, hair, milk, and feces).

In the initial period, mineral elements most likely deficient and needed in supplements were P, Cu, Se, and Zn. During the experimental period, K was found to be deficient in soils during both seasons. Forage seasonal differences ($P < .05$) were found for Ca, Mg, K, and Na, higher in the wet vs dry season. Of the six macro elements

studied, K in soil, crude protein, P, Na, K, and Mg in forage and Ca, P, and Mg in animal tissues were most likely to be deficient.

The most pronounced finding from the analysis of samples for micro elements was the low Se status of pasture, soil and animal tissues. On the basis of Se analysis, combined dietary and injectable Se plus vitamin E resulted in higher ($P < .001$) tissue levels. Of the seven trace minerals studied, Cu, Mn, Zn, Co, and Se in soil, Cu, Se, and Zn in forages and Se in animal tissues were the most likely to be deficient. Mineral supplementation improved Zn and Se status of animals.

Increasing Se intake of cows resulted in higher serum Se concentrations of their calves suggesting that Se did cross the placental membrane. However, due to low concentration of Se in milk, calf serum Se decreased rapidly to values as low as .015 ug/ml in 3 months compared to .086 at birth. Treatments had no effect ($P < .05$) on blood metabolic profiles, vigor and nursing response of calves.

CHAPTER I
INTRODUCTION

In many tropical and warm climate regions, mineral deficiencies, imbalances or excesses are severely inhibiting the cattle industry (Conrad, 1978). Often livestock grazing in warm climate regions do not receive adequate mineral supplementation, and forages rarely satisfy mineral requirements completely. In general, central Florida soils (Entisols) are acid and low in natural fertility (Yuan, 1963, Zelazny and Fiskell, 1971). The formation of these poor soils has been one of the major problems of the beef cattle industry in Florida because of poor pastures that have been growing on these soils.

The Brahman breed of beef cattle represents a different species, Bos indicus than the breeds of European ancestry, Bos taurus. Therefore, it is possible to obtain hybrid calves with increased vigor and tolerance to tropical environments than for the Bos taurus by systemic crossbreeding of purebred Brahman with Bos taurus breeds. In general, reproduction rate is lower and calf mortality is higher in purabred Brahman, thereby reducing their beef production efficiency at least 10% below most other beef breeds. In areas of the world where beef and dairy cattle enterprises depend on natural or improved grassland for supplying of nutrients, animals are likely to be subjected to undernutrition during the dry period of the year. During those periods, herbage will have low nutritive value, the most overriding

factor being a shortage of digestible energy and protein. Cattle grazing such herbage are unable to meet their requirements for maintenance and generally growth, reproduction and lactation are impaired.

The introduction of new pasture grasses, application of fertilizers to pastures and use of mineral supplements for cattle have markedly changed fertility of soils and mineral status of forage plants as well as animals. As a consequence of these modern cropping systems, acute mineral deficiencies in grazing animals have disappeared in Florida (Becker et al., 1965). The use of mineral supplements have been found to be inadequate in many cases, and subclinical mineral deficiencies, as assessed by low tissue concentrations, have been reported to be widespread around the world (McDowell, 1976, Ammerman et al., 1974).

Since the research initiated in 1927 by Becker et al. (1965), little systematic mineral research has been designed to study the general status of cattle in Florida. The present experiment is 1) to study the mineral status of Brahman purebred beef cattle in central Florida, and to investigate the effect of mineral supplementation, and season of the year on tissue mineral concentrations, 2) to study the effect of season of the year and locations on the mineral status of forage and soil, 3) to evaluate the possibility of correlation between dam's mineral supplementations and calf vigor and nursing response, and 4) to compile data of blood profiles for Brahman calves at birth, 3 days and 3 months of age.

CHAPTER II
LITERATURE REVIEW

Mineral Status of Soils

Soils of Florida

The new system of soil classification recognizes four major soil orders in Florida. Among these orders, the Spodosols are the most dominant soils followed by Entisols, Ultisols and Histosols (Johnson and Carlisle, 1976). The Spodosols are mostly found in the southeast and southwest of Florida. The Entisols are mainly located in the extreme south and central Florida. The Ultisols are mostly found in the northwest of the state, while the Histosols are mostly located in the everglade region of south Florida.

The majority of Florida soils have developed from relatively coarse-textured, highly weathered materials. In general, these soils are acid and low in natural fertility. The source of acidity in these soils is mainly exchangeable Al and then H formed by release of proton from Al polymers and organic matter (Yuan, 1963; Zelazny and Fiskell, 1971).

Soil acidity affects plant growth in several ways. Al and Mn may be in toxic concentrations, Ca and other nutrients may be deficient, P availability may be low, and multiple nutrient deficiencies from inhibition of root growth may occur (Adams and Pearson, 1967; Kamprath, 1972; Reeve and Sumner, 1970; Black, 1968). The neutralization of acid soils with lime has been studied for a long

time with the objective of determining the best solution to soil acidity problems.

Originally, lime was applied to increase pH to neutrality. However, Adams and Pearson (1967) indicated that it is unnecessary to lime to neutrality. The beneficial effects of liming are largely due to inactivation of exchangeable Al (Ragland and Coleman, 1959). Blue and Dantzman (1977) summarized the problem associated with high Al and Mn; these can be eliminated in surface soils by liming to pH 5.5. However, it has been suggested that old highly weathered soils in the eastern United States, which are poorly buffered, should be limed to pH 5.0 to reduce frequency of reliming and provide more desirable conditions for plant growth, especially legumes (Blue and Dantzman, 1977). Yuan et al (1977) reaffirmed that soil pH changes are controlled largely by buffering capacity which varies with the soil and increases in order of Ultisol, Entisol and Spodosol. He concluded that it is necessary to consider the buffering capacity before liming.

Mineral content of a soil ultimately depends on the parent rock from which the soil was derived. However, little relationship was found between soil chemistry and mineral composition of native vegetation and farm crops growing on that soil (Hemphill, 1977, quoted by Raith and Horvath, 1980). Consequently, mineral intake from plant consumption by animals depended more on what plants were eaten and in what quantity than on the parent rock from which the soil was derived and on which the plants were grown (Hemphill, 1977, quoted by Raid and Horvath, 1980).

Calcium, Phosphorus, Aluminum, Iron and Soil Acidity

It has been observed that when lime is applied to an acid soil, movement in solution occurs toward the bicarbonate form. This is because the partial pressure of Co_2 in the soil is high enough to cause a reaction with the hydroxide and even the carbonate. When $CaCo_3$ reacts with acid soils, Ca replaces H on the colloidal complex. The continued removal of H^+ from the soil solution will ultimately result in precipitation of Al and Fe and their replacement in the absorption sites by Ca and other basic cations (McLean, 1971; Brady, 1974). McLean (1971) also observed that through stimulation of microbial activity by lime, organic substances such as gums and resins are produced which coat and stabilize mineral aggregates. The same effect was observed for the detrimental effects of Ca on Fe and Al.

The cation exchange capacity (CEC) is also affected by pH. The higher the pH of a solution, the higher the measured CEC, the lower the calculated degree of base saturation and the greater the apparent acidity of the soil (Coleman and Thomas, 1967). Fiskell (1970) found that organic matter is the main source of cation exchange sites in Florida soils. Then, Fiskell and Zelazny (1971) stated CEC values increased with increase in pH, particularly in surface soils. Increases in CEC were attributed to increases in pH dependent charges on the organic matter.

The effect of lime on P availability has been studied by many researchers. At low pH values and on soils high in Al and Fe, phosphates are rendered less available because of their reaction with these compounds. The addition of a liming agent to these soils will reduce the positive charge from Fe and Al, thus increasing the level

of available P (Tisdale and Nelson, 1975). If the soil pH is greatly increased by the addition of excessive amounts of lime, P availability will again be decreased because of its precipitation as calcium phosphates (Kamprath, 1971; Tisdale and Nelson, 1975). Blue (1971) found that the relationship between Ca levels and P retained was linear from pH 4.5 in a virgin Spodosol to pH 7.5. Valaz and Blue (1974) increased yields of pangola digitgrass (Digitaria decumbens stent.) on a heavily limed Entisol from Costa Rica only after additions of extremely high P rates. Subsequently, Reeve and Sumner (1970a) concluded that heavy lime applications decreased P availability.

During early investigations, low soil pH and the presence of high H ions in solution were thought to be the major causes of poor root development. Today, however, strong evidence indicates that poor development of root and plants grown on acid soils is mainly due to the presence of high exchangeable Al and Mn. Blue and Dantzman (1977) in a research review indicated that Al concentration in soil solution on the order of .45 ppm is toxic to plants in most mineral soils. Fertilizer salts such as potassium chloride (KCl) have been reported to increase Al saturation in the soil solution which resulted in poor root growth (Ragland and Coleman, 1959). Toxicity of Al is mainly due to the trivalent ion Al^{3+}. Al, Mn, and Fe due to their hydrolysis capacity are the major source of soil acidity in mineral soil (Tisdale and Nelson, 1975).

Phosphorus Deficiency

Study of availability of P is very important because P is probably the most deficient nutrient in acid soils (Blue, 1974) Therefore, crop establishment and development in tropical acid soils are often impossible without P applications (Blue, 1969). From a fertility standpoint, the formation of insoluble Al and iron phosphate complex has been reported to be the major cause of P deficiency in tropical and subtropical soils (Reave and Summer, 1970). However, today information has been accumulated to show that absorption of P by Al is to some extent a mechanism of preventing P from leaching out of the soil surface. Robertson et al. (1966) reported that a single large application of P to high P fixing soils was not only more economical in labor, but also maintained soil P available to plant crop for more than five years. Phosphorus from aluminum phosphate is slowly released into soil solution and may be available to plants for long periods of time. Similar results have been reported in Florida sandy soils where P applied in large quantities was still available to corn after six years of single application (Hutton and Robertson, 1961). Studies with acid soils have shown that in some instances plant growth was decreased and plants exhibited P deficiencies when limed above pH 7.0 (Pierre and Browning, 1935). They found also that growth of corn was considerably less at pH 7.0 as compared with ph 5.8 with normal rates of P fertilization. Andraw and Johnson (1976) stated that P concentration in plants was higher at low soil Ca levels than at higher concentrations.

Aluminum toxicity represents a combination of effects of which inhibition of root growth is perhaps the most obvious. As a result, the plant may have multiple nutrient deficiencies (Black, 1968). Abruna et al. (1974) working with green beans on fine Ultisols and Oxisols found that exchangeable Al was reduced to nontoxic levels at pH 5.2.

Manganese, Copper, Molybdenum, and Zinc

For some trace elements (Mn, Fe, Zn, Cu and Co), there is a negative relationship between the pH and the quantity of the mineral available to the plant, while for others (Mo and Se), it is positive (Pfander, 1971; Hartmans, 1970).

According to Leeper (1947), soil acidity is the major factor affecting Mn availability. In acid soils, with pH near 4.0, soluble divalent Mn is the most available. Organic matter has the property of a reducing agent and thus causes an increase in Mn solubility. Anaerobic conditions such as seasonal water logging will result in reduction of the manganese oxide by anaerobic soil bacteria. This reduction is a potential source of available Mn in soils.

Fleming (1973) indicated that Mn is probably the most sensitive mineral to pH change. Fleming also reported that a reduction in soil pH by one unit doubled the Mn content of perennial rye grass, while raising soil pH by one unit lowered the Mn content of the grass by half.

Excess of Mn is a factor of substantial importance in acid soil infertility (Adams and Wear, 1957; Tisdale and Nelson, 1975). Adams and Pearson (1967) stated that the amount of easily reducible

Mn in the soil will determine the potential for toxicity and that minimum levels of 50 to 100 ppm are necessary for Mn toxicity to occur in soils of the southern United States. However, experiments with nutrient solutions containing less than 10 ppm of Mn have shown Mn toxicity in Senegal lagunes. Generally, a few ppm Mn in the soil solution is enough to induce Mn toxicity. Manganese toxicity is one of the hazards of plants growing in acid soils and, like Al toxicity, can be avoided by proper use of lime (Adams and Pearson, 1967).

MacKay et al. (1966) reported that Cu and Mo have a mutual antagonism in the soils. The concentration of one element in the soil may affect the uptake of the other by plants. Studies on the interaction between S and Mo in soils, and concentrations of Mo, S, and Cu (Gupta and MacLeod, 1975) in plants indicated that the application of .5 to 1 ppm Mo to the soil produces forages containing Mo values in the range of 2.13 to 8.14 ppm for timothy, and 2.80 to 15.18 ppm for red clover. Copper concentrations of these samples ranged from 7.9 to 8.4 ppm in timothy and 10.5 to 10.6 ppm in clover. However, when 60 to 200 ppm S were added to the soil together with Mo, plant Mo concentrations fell drastically. By contrast with Mo and Zn, changing soil pH does not affect the absorption of Cu by plants due to adsorption of Cu^{2+} on organic and inorganic colloids (Longaragen, 1975). According to Large (1971), 2 ppm Cu in the soil solution should be adequate for most crops, with the exception of vegetable crops grown on organic soils. Herowitz and Dantas (1973) reported that normal soils had between 2.2 and 79.4 ppm Cu in the surface horizon. The authors also indicated that soils with less than

6 ppm extractable Cu were considered to be deficient for pastures and crops.

Krauskopf (1972) indicated that soil analyses for Mo show a wide range, but generally less than 5 ppm. Available Mo as a rule is high in alkaline soils rich in organic matter and young soils derived from volcanic soils. According to Large (1971), a soil level of .4 ppm Mo is adequate for most crops. Molybdenum is normally not recommended for non-legume crops until the soil level reaches less than .2 ppm Mo.

Acid soils often fail to supply adequate amounts of Mo for good growth of plants. Yield response to applied Mo becomes smaller as soil acidity decreases (Jackson, 1967). Nevertheless, in some cases where the native Mo is very low, response to applied Mo has been noted even at high liming rates. A pH of 6.5 is required for maximum availability of soil Mo. However, at this pH, the availabilities of some of the other micronutrients may limit plant growth more than Mo availability except for the growth of legumes (Kemprath, 1972).

The solubility of Zn^{2+} is highly pH dependent and decreases 100-fold for each unit increase in pH. Zinc deficiencies induced in acid soils by overliming can be easily explained by this pH dependent relationship (Lindsay, 1972). Lange (1971) indicated that the soil Zn level should be maintained between 8 and 10 ppm, however, the recommendation must take into account the soil P level as well as the soil pH. The repression of Zn by P is mainly physiological and occurs at the root surface or root cells. Translocation of Zn from the roots to tops of plants is inhibited by elevated phosphorus concentrations in plant tissues (Stukenholtz et al., 1966). However, increasing soil K reduces the depressive effects of P on Zn. Although Zn and

Cu have similar responsas as pH changes, Cu deficiencies in plants are less prevalent than Zn in high pH soils. This can ha explainad by the fact that Cu forms a complex with soil organic matter which may influanca Cu availability to plants on alkaline soils (Hodgson et al., 1966).

Potassium, Sodium and Magnesium

Potassium availability is also aifected by lime. Obviously, liming can increase plant afficiancy in tha use of K simply by removing othar growth-limiting factors and improving the positional availability of K through an expanded and more efiective root system. In addition, liming may decrease leaching losses of K. Liming tends to increasa reversion of K to lass solnble forms, and may or may not afiect the rata of release of nativa minaral K into solubla or axchangeabla forms (Peech and Bradfield, 1943; Rodgers, 1948). Leaching loss of K was substantially reduced by even modest applications of lime (Ayras, 1961). In addition, Nolan and Pritchett (1960) reported that leaching of K from Lakaland fina sand at pH 4.2 was 1.75 times greatar than at pH 5.3 and 2.75 times greater than at pH 6.3. Tisdale and Nelson (1975) also indicated that soils of the southeastarn and southarn coastal plain areas of the United States are generally poor in K because they were formed from marina sediments which hava baan highly laached. Gammon (1967) indicated that leaching of K in Florida soil is so high that annual application of K should be recommended in Florida soils to maintain good crop production. Khomvilai and Blue (1977) reported that in Ultisol, Spodosol K retention was increased after $CaCo_3$ application up to 2 meq/100 g increment. Higher liming rate decreased K retantion. In Entisol,

however, limed soils showed a decrease in K retention at all liming rates.

Tisdale and Nelson (1975) indicated that Na was one of the most loosely held of the metallic ions and was readily lost through leaching. Its presence in soils in fairly high quantities is restricted to arid and semi-arid regions. Plant uptake of this element is as Na^+ ion, and mostly from soil solution.

Magnesium deficiency may occur in acid soils with low cation exchange capacity, high leaching potential, excessive K and Ca, and with crops with high Mg requirements (Adams and Pearson, 1967). The total Mg taken up by plants was not related to total Mg levels in the soil, percent clay in the soil, or exchangeable Mg levels. Instead, Mg of plants appeared to be related to the mineralogy of the medium clay fraction (Christenson and Doll, 1978).

Cobalt and Selenium

The availability of soil Co is affected by the Ca content of the soil. Calcium interferes with the uptake of Co by the herbage even if Co is supplied as a top dressing (Robertson, 1971). From Florida pastures, soil samples were collected from specific sites to relate cattle status to the composition of the soil. The acid soluble Co in 13 soils from healthy ranches varied between .023 and 1.3 ppm, averaging .190 ppm. Eighteen "salt sick" (a combined Co, Cu and Fe deficiency) soils contained .001 and .07 ppm of acid soluble Co and averaged .01 ppm (Becker et al., 1965).

Soil ingestion can greatly affect mineral intake. Soil ingestion is favored by grazing intensity, low pasture availability and cold winter months. Soil ingestion by sheep and cattle can constitute 10

to 25% of total dry matter intake. This ingestion can be beneficial with elements such as Co or I and, in some circumstances, with Cu, Zn and Se (Underwood, 1979). The uptake of Ca by plants is greatly affected by soil pH, Al, Fe and Ca (Gille and Graham, 1971). The authors observed this effect in an experiment with Sudan grass grown in soils where pH varied from 4.5 to 7.5 with added levels of Al, Fe and Ca. The results indicated that plants grown on soils with a pH range of 4.5 to 5.5 with added Al, Fe and Ca accumulated higher amounts of Co than the control plants grown on soil with the same pH. Cobalt deficiency in the United States was expected to occur mostly on sandy Spodosols. In the lower Atlantic Coastal Plains extending from North Carolina to Florida, Co deficiency in soils, plants and animals was most found in seasonally flooded lowlands (Kubota, 1968).

Soil Se exists in many different forms, but mostly in the form of selenite associated with Fe as an Fe-selenite complex which is less available to plants. Selenates were the most soluble in acid soils having significant amounts of Fe. In alkaline soils, however, selenites tend to oxidize to more soluble forms such as selenates (Allaway et al., 1967). According to Cary et al. (1967) and Ammerman et al. (1978), the total Se content of a soil shows very little relationship to the concentration of Se in the plants grown on it. This lack of dual relationship may be due to the fact that Se is present in the soil in different chemical forms that have a varied availability to plants. Cary et al. (1967), in an experiment with United States soils, indicated that the Entisols of Florida contained more soluble Se than any other soil. Similarly, the leaching of Se in Entisols was higher than other soils. The authors concluded that

Entisols are predisposed to contain toxic levels of Se as well as deficient levels because of the high solubility and high leaching of Se in these soils. The authors suggested that, to prevent Se deficiency in these soils, a synthetic complex of selenite plus hydrous sesquioxides may be the best form of Se to be used in soils with low Se fixing capacity. This form will ensure continuous availability of Se to plants due to the fact that it resists oxidation to soluble selenate in alkaline soils and resists reduction to inert elemental Se in acid soils. From Florida, McDowell et al. (1982) reported that soil Se ranged from .020 to .038 ppm, with all samples containing less than the critical level (<.5 ppm).

Mineral Status of Forages

Calcium, Phosphorus, and Nitrogen

Calcium deficiency in forage for grazing ruminants is rare, but is one of the most deficient minerals in warm climate regions. The NRC (1976) recommendation for a nonlactating beef cow weighing 450 kg is .18 percent P in the dry matter consumed. For a lactating beef cow also weighing 450 kg with average milking ability, the recommendation is .28 percent Ca and .28 percent P in the dry matter consumed. Kirk et al. (1970) indicated that in Florida the critical forage period was usually from December to March (winter). This is because of the slow growth rate of pastures and the low mineral contents of forages during this period. Gross signs of P deficiency, evidenced by drastic loss of weight in cattle, low plasma P, and by chewing of pine knots and palmetto roots were noted during this period. Hodges et al. (1964) confirmed this observation by reporting P deficiency in nursing cows grazing unfertilized pangola grass

pastures on Immokalee fine sand soils in central Florida. The affected animals chewed bones, exhibited weight loss and appeared unthrifty. Forages from affected areas contained low phosphorus levels on order of .12 percent

In plants, P is an important constituent of a number of biologically important organic compounds such as nucleoproteins, sugar phosphate, ATP, etc. Phosphorus deficiency signs include chlorosis and death of older leaves, greatly reduced plant size and purple coloration due to anthocyanin production (Whiteman, 1980). Low P concentrations in Florida forages can be increased from values of .07 percent to .30 percent by P fertilization The authors also noted a significant increase in weaning percentage of calves, production per cow and weight gain per acre following P fertilization.

Underwood (1966) indicated that Ca deficiency was rare in grazing cattle, except for high producing dairy cows or cattle grazing on acid and sandy soils of the humid areas devoid of legumes. Playna at al. (1978) reported that under Australia conditions, legumes may contain 2.2 to 5.2 times greater Ca concentrations than grasses. However, in legumes, Ca tended to decrease with increasing maturity of the plants, while in grasses, Ca concentrations remained constant throughout the year. Native Florida pastures have been reported to have low dry matter yields and be deficient in certain plant nutrients. Among macronutrients studied, P and to some extent Ca were reported to be a serious problem. Becker at al. (1965) indicated that, on pastures where animals were suffering from "salt sick" disease, low mean values on the order of .13 percent Ca and .12 P were very common. The authors pointed out that the levels of P and Ca can be increased by

management, the practice of burning the pasture at a certain period of the year. Chemical analysis indicated that early spring forages from the burned pastures contained .17 and .20 percent Ca and P, respectively, compared to .16 percent Ca and .16 P on forages from the unburned pastures (Becker et al., 1965). However, the effect of burning was of short duration, and was followed by a drastic monthly decrease of forage Ca and P levels (Becker et al., 1965). Becker et al. (1933a) indicated that most of the dairy cattle feeds in Florida were based on grass pastures and silages which are low in Ca. Dairy cattle grazing wiregrass with .16% percent Ca and fed corn silage containing .08% percent Ca were later reported to have broken pelvises, hips and ribs.

In many types of vegetation, the Ca level will remain relatively high throughout the year, but P may be easily leached out and by mid-winter, as much as 55% of the P may be lost (Thompson, 1978). Du Toit et al. (1940) reported forage P concentrations ranging from .12 to .17 percent in the wet season compared to .05 to .07 percent during the dry season. In a study of tropical forages, Gomide (1978) reported that the age of the plant is an important factor affecting the chemical composition and nutritive value of the forages. Phosphorus levels decrease with age of the plant and this dilution follows a sigmoidal curve with time. Phosphorus is extremely mobile, shifting from old plant tissues to new ones. However, Ca is relatively immobile and increasing concentrations are found in old organs and in the stem. He showed that the difference in mineral composition among forage species is low with few exceptions.

Walker et al. (1976) reported Ca, P, Mg, Mn, and Se values for five varieties of alfalfa grown at six locations; the mineral content was not significantly affected by variety, but was greatly affected by location. Correlation analyses showed positive correlations between Ca/Mg, P/Se, Se/Crude protein and a negative correlation between P/Mg.

According to NRC (1976), depressed appetite is the primary sign of protein deficiency in beef cattle which leads to an inadequate intake of energy, thus, protein and energy deficiencies occur together. Milford (1960) indicated if energy balance is positive and crude protein digestibility is around 45-50% crude protein concentration of 7.2% in forages is sufficient to give 0 nitrogen balance. Minson (1971) estimated the critical level of crude protein in pasture to be between 6 and 8.5%, lower crude protein contents may limit feed intake. Moore and Mott (1973) suggested that crude protein percentage be examined first when an explanation of an unexpected low production is observed before looking for other limitations such as those related to forage structure, other nutrients and toxic agents. From South Africa, Du Toit et al. (1940) reported that protein showed a seasonal variation ranging from 7 to 9 percent in the rainy season to 3.3 to 4 percent during the dry season. Supplementing animals with P and protein reduced greatly the interval from calving to first postpartum estrus and animals were heavier than those without protein-phosphorus supplementation (Little, 1975; Schur, 1968).

Potassium, Sodium, and Magnesium

Potassium is present in plants in quantities greater than that of any other mineral (Black, 1968). In general, forages are low in Na and a deficiency in forages is common. The NRC (1976) requirements

for K for growing and finishing steers is .60 to .80 percent of dry matter intake and the requirement is .05 percent for Na. Griffith and Walker (1966) reported that increasing the K level in the soil medium is known to reduce the Na content of grasses. Kemp (1960) found that K content of herbage is considerably influenced by N fertilization. When pastures were heavily dressed with N, there was a marked increase in forage K. This mineral is taken up by the plants in large quantities during their vegetation growing period.

Generally, Na and Cl, along with K, function in maintaining osmotic pressure, regulating acid-base equilibrium and controlling water metabolism in body tissues. They help control the passage of nutrients into the cells and products out. Peaslee and Moss (1966) reported that the rate of photosynthesis in corn leaves was closely related to concentration of K and Mg in the leaves. Leaves of K stressed plants showed a decreased photosynthesis rate, although the plant appeared normal. In Mg deficient plants, however, the photosynthesis did not decrease until the appearance of chlorosis. Hannawalt and Whittaker (1977) reported that the concentration of available Na and K generally was higher in dot dry climate than cool and moist climate.

Forages are highly variable in Mg, with legumes generally higher than grasses (Nelson, 1973). Gomide (1978) reported that Mg is almost immobile in plant tissue and concentrations increase in the oldest organs and stems. Thompson and Troeh (1978) point out that characteristics of Mg inside the plant resemble those of K much more than those of Ca. Gomide et al. (1969) studied six tropical grasses and found that Mg levels were different among grasses ($P < .05$), plant

age ($P < .01$) and between years ($P < .05$). The NRC (1976) requirements for growing and finishing steers and heifers is .04 to .10 percent (dry basis)

Copper, Molybdenum, and Iron

Copper is an important constituent of several plant proteins and enzymes, i.e., cytochrome oxidase, ascorbic acid oxidase, etc. Molybdenum has long been known to be required for the normal assimilation of N in plants.

The exact minimum requirement of Fe for cattle is not yet established. The NRC (1976) estimated a requirement of 10 ppm Fe for growing and finishing steers and heifers. Cows may require a similar amount. Copper requirement for growing and finishing steers is 4 ppm, the requirement for dry, pregnant or lactating cows is unknown, but it is suggested that the level for the growing and finishing animals be used. Davis (1954) indicated that in most Florida forages, Cu concentrations on the order of 5 ppm were adequate for cattle nutrition when Mo in the forage was less than 1 ppm. In pastures with Mo content of 2 to 3 ppm, forage Cu should be at least 10 ppm while feeds containing higher Mo would result in Cu deficiency unless copper was 50 ppm or more.

Berry and Reinsenauer (1967) found that plants deficient in Mo showed the lowest rate of Fe uptake while moderate Mo levels enhanced Fe uptake. High Mo, however, greatly reduced Fe absorption by plants. It was reported that there is a three-way interaction between Cu, Mo, and S (Underwood, 1979). This author also adds that it now seems that the primary interaction site is in the gut, with three steps postulated as follows; reduction in the rumen of sulfate to sulfide,

reaction of this sulfide to form thiomolybdate, reaction of the thiomolybdate with Cu to give the highly insoluble and unavailable Cu-thiomolybdate. It is important to appreciate that Mo can interfere with Cu metabolism at well below 5 ppm Mo or more than has occurred under experimental conditions or occurring in molybdenosis (Underwood, 1979).

Underwood (1977) reported that Cu toxicity may develop in sheep grazing pastures containing 10 to 15 ppm and extremely low levels of .1 to .2 ppm of Mo. Therefore, if the Mo level falls below .2, it is advisable to examine the Cu level, because toxicity for sheep can easily result in the presence of low Mo levels. Neathery (1976) reported that the tolerance levels for Mo ranged from 5 to 50 ppm and the tolerance levels for Cu, 100 ppm of DM. Miltimore and Mason (1971) suggested that Cu deficiency was likely to occur when Cu:Mo ratio was less than 2:1. Copper deficiency in cattle as evidenced by typical signs of pacing, fading of hair coats, falling disease, and response to Cu supplementation was among other mineral deficiencies reported in Florida cattle (Becker et al., 1365). Most forages commonly used in feeding farm animals contain large amounts but highly variable concentrations of Fe. The Fe content of herbage plants is a reflection of the species and the type of soil upon which the plant grows (Underwood, 1966). Sonsa (1978) analyzed forage Fe as related to season and grass interaction and found the highest mean during the dry season to be 586 ppm for native grass and the lowest value, 130 ppm, for guinea grass. Chapman and Kidder (1964) suggested that under Florida conditions, a mineral mixture that is consumed at the rate of 35 to 40 pounds per animal per year should contain at least .15

percent Cu for cattle on mineral soils, and .75 percent Cu for organic soils. Cattle grazing pastures on organic soils need more Cu to offset the effect of high forage Mo. Under natural conditions, Fe deficiency is not likely to occur in cattle (Underwood, 1977). In Florida, however, iron deficiency has been reported for cattle grazing on sandy soils (Becker et al., 1965).

Manganese, Cobalt, and Zinc

The Mn requirement for growth of cattle is low, usually 1 to 20 ppm of diet dry matter. However, with high levels of dietary Ca and P, the Mn requirement is apparently somewhat elevated. Mn is often abundant in pastures, and most forages contain more than 30 ppm Mn which is apparently adequate to meet the requirement of 10 to 20 ppm Mn for heifers and cow (NRC, 1976). The Mn levels in forages are extremely variable. This variation reflects substantial species differences as well as soil and fertilizer effects (Underwood, 1977). Gomide et al. (1969) reported N fertilization increased ($P < .05$) the Mn content of the grasses an average of 41 ppm. It was reported that heavy liming decreased Mn uptake by some grasses and created Mn deficiency in cattle grazing these pastures (Lucas, 1969; Ankn nt al., 1973, Zantua and Blue, 1971). Hartmans (1974) indicated that protein, Cu, P, and K decreased Mn utilization and increased its requirement for grazing cattle. The author suggested that, under Netherlands conditions, 25 ppm Mn in the diet was considered marginal.

Cobalt has not been demonstrated as essential for the growth of higher plants. Reisenhauer (1960) reported that Co plays an important role in N fixation by bacteria. The NRC (1976) Co requirement for growing and finishing steers and dry, pregnant, or lactating cows is

between .05 and .10 ppm. Possible toxic levels are above 10-15 ppm dry matter. Houser et al. (1978) indicated that forage Co is more useful in measuring Co adequacy, since there seems to be a direct relationship between the forage Co and the health of ruminants grazing that forage. According to these authors, it appears that less than .10 ppm Co in the forage should be considered deficient. Substantial species differences have been reported between grasses. Beeson et al. (1955) reported Co concentrations to range from .05 to .14 ppm, Cu from 4.5 to 21.1 ppm and Mn from 95 to 815 ppm (DMB) for 17 grass species grown together on a sandy loam and sampled at the same time. Studies by Reith (1970) have shown that N fertilizations have no effect on Co, Cu, and Zn content of grasses provided the soil is supplied with these elements. However, N fertilizations reduced Mn and Mo concentration of grasses even when the soil supply was adequate.

A Cobalt deficiency in Florida has been reported to be a serious problem associated with a disease called "salt sick" as described by Becker et al. (1955). The authors found that pastures, with 'salt sick" cattle, contained .001 to .07 ppm acid soluble soil Co and .000 to .035 ppm forage cobalt. In Queensland, Winter et al. (1977) indicated that deficiency of Co in grazing animals may be related to the presence of sandy soils low in Co content and to the seasonal variation of Co concentrations in forages. The authors added that some forages of the region may contain .125 ppm Co in the wet season, while this level may decrease to .005 ppm near the end of the dry season. Ammerman (1970) reviewed the literature on interrelationships between Co and other dietary factors and found Co to interact with Fe,

Cu, Se, and Mo. The deficiency signs of acute Co deficiency include lack of appetite, rough hair coat, thickening of the skin, anemia, wasting away and death. In addition to the importance of Co as a component of vitamin B_{12}, it is believed to have other functions in the body such as activating ion in certain enzymes. Evidence to support these functions has not been forthcoming (Houser et al., 1976)

Dynna and Haure (1967) reported that bulls which were fed hay containing less than 30 to 40 ppm Zn and less than 5 ppm Cu were unthrifty, with poor growth, and developed depigmentation and loss of hair around the eyes and also parakeratotic skin changes. Copper supplements were partially effective while Zn alone seemed to aggravate the condition. Administration of a mixture of Cu and $ZnSO_4$ had a dramatic affect. Naturally occurring Zn deficiencies in grazing animals are rare. However, McDowell et al. (1978) states that in recent years deficiency in grazing animals has been reported in several countries when the Zn content of the diet was less than 40 ppm. The NRC (1976) Zn requirement for growing and finishing steers is 20 to 30 ppm, but the requirement for dry or pregnant cows is not known. It is suggested that the level for the growing and finishing animals be used. The solubility of Zn^{2+} is highly pH dependent and decreases 100-fold for each unit increase in pH. Zinc deficiencies induced in acid soils by overliming can be easily explained by this pH dependant relationship (Lindsay, 1972). Safaya (1976) reported that an excess of P inhibits Zn uptake by plants through two mechanisms, decreasing its translocation through the epidermis and lowering its rate of absorption through the surface cell layer of the roots.

Underwood (1977) indicated that forage Zn concentrations tended to decrease as the plants matured. Similarly, Perdomo et al (1977) reported decreased Zn levels in forages harvested after 56 days compared to younger plants. Conditions such as high N and P content of soils have also been reported to decrease Zn uptake by plants (Ozanne, 1955; Sharma et al., 1968). The severe clinical Zn deficiencies are of less economic importance than borderline subclinical deficiencies. The first effects of a mild Zn deficiency would be expected to be decreased feed intake, growth, feed efficiency, milk production, resistance to infection and stress, and lower productive efficiency (N J. Miller, 1970). A borderline Zn deficiency, which is more likely to occur, would be difficult to diagnose clinically. As an illustration, Mayland (1975) reported increased weight gains for cattle supplemented with Zn, in absence of Zn deficiency signs.

Selenium Status of Forage

Allaway and Hodgson (1964) found a high correlation between forage Se contents and the geographic distribution of muscular dystrophy in livestock. Forages from regions showing white muscle disease in ruminants contained less than 1 ppm Se.

Allaway et al (1967) indicated that, among the forms of Se found in the soils, selenates were the most soluble. In acid soils having significant amounts of Fe, Se is mostly in the form of selenite associated with Fe as an Fe-Se complex which is less available to plants. In alkaline soils, however, selenites tend to oxidize to more soluble forms, selenates (Allaway et al., 1967).

The Se requirement of beef cattle depends on the amount of vitamin E in the diet, but it is approximately in the range of .05 to .1 ppm of dry matter. Until a few years ago, Se was considered in beef cattle nutrition only as a toxic element. Se toxicity may occur when cattle consume feed for extended periods containing 10 to 30 ppm Se dry matter basis (DMB)(NRC, 1976). From Florida, Shirley et al (1966) reported Se concentrations of .02 to .03 ppm in white clover on sandy soils, and .04 to .06 ppm in St. Augustine grass on Okeechobee peat muck soils. These levels were below .1 ppm Se suggested by NRC (1976) as the minimum requirement. The authors also found that Se injections up to 5 6 mg every 60 days have no effect on heifers grazing Se deficient pastures. More recently, McDowell et al (1982) found mean forage Se varied from .02 to .08 ppm among regions and was .02 and .13 for the wet and dry seasons, respectively. Of all forage samples analyzed, 84.2 and 90.0% were deficient (< .1 ppm) during the wet and dry seasons, respectively.

Plants vary considerably in their uptake of Se, some contain as much as 10,000 ppm (DMB) while others grown at the same location contain 30 ppm (NRC, 1976). Acute Se poisoning is most often associated with consumption of Se accumulator plants which may contain from 100 to over 9000 ppm Se and emit a strong characteristic odor. The best known Se accumulator plants belong to a certain species of the genera of Astragalus, Stanleya, Donopsis and Zylorrhiza (Underwood, 1966). Antagonism of S on Se uptake by plants has been reported in many experiments. Hurd-Karrer (1938) found that sulfate counteracted Se toxicity in grazing animals. He also reported that

sulfate markedly reduced the uptake of selenate by plants, but had little effect on selenite.

The Use of Comparative Blood Profiles to Measure Effects of Dams' Minerals Supplementation on Brahman Calf Survival

The weak calf syndrome (WCS) is a disease entity of newborn calves that has plagued the cattle industry for decades. The incidence of weak calf syndrome is not uncommon in Brahman herds. A review of literature on mortality of newborn calves revealed many contributing factors to Brahman calves' disorders at birth but provided very little evidence for the cause(s). The syndrome has been recognized by a variety of names including weak calf syndrome, dummy calves, idiopathic polyarthritis, ward's syndrome, bitterroot crude, empty bank account and other descriptive terms. Investigation of the WCS problem has involved a number of workers at the Montana State University, University of Montana, University of Idaho, National Disease Center, Washington State University, University of Florida and veterinarians in the field.

Dams giving birth to calves with WCS show clinical symptoms of anorexia, loss of weight in the last two months of pregnancy, and abnormally high temperature ranging from 102-105° F accompanied by labored breathing. However, there is no sign of dystocia and the fetuses in these cows are in normal position and apparently of normal size. Calves from such cows are usually weak and unable to withstand stress conditions which commonly occur within the first few days of life. The dams show no maternal instinct, which decreases the probability of the calves' survival.

The real cause of the WCS still remains undetermined, however, there are known contributing factors which may have been repeatedly

identified. Bad weather conditions are not the sole causative factor, but only a prime contributing agent, because weak calves have been born in near perfect environmental conditions. Nutritional status of herds has been listed as an important subject for consideration and research. Hull et al. (1974) indicated a direct correlation between the incidence of WCS and the level of crude protein intake per cow per day during the last 60 days of gestation. In addition to protein, other nutrients including vitamins and minerals have been reported or suspected to be contributing factors.

Waldhalm et al. (1974), Ushijima and Ward (1975), McClurkin and Coria (1975), Stanchar et al. (1974), and Page et al. (1969) have isolated a series of bacterial, mycoplasmal and viral agents. These infectious agents have further obscured the real cause or nature of the cause. Up to the present time, the real cause of WCS is unknown. However, the areas of nutrition and infective microbial agents promise hope, challenge, and clarification for the cause(s) of this economically devastating disease.

Considerable emphasis has been placed by some on the use of livestock metabolic profiles in assessing nutritional status and production potential. The usefulness of blood chemistry tests depends upon the proper interpretation of test results. Hanston et al. (1977) noted that more comprehensive knowledge of interacting effects of age, rate of growth, and system of husbandry upon blood composition of cattle was needed before any type of metabolic profile test could be devised for application to the beef producing industry. However, there are few established values for the 25 blood components, nor is there a good representative datum collection of blood profile values

es related to Bos Indicus. The usefulness of the blood profile is also limited by the sampling problems, low correlation with nutrient intake, inconsistent pattern in disease, and the difficulties in interpretation of the profiles (Adams et al., 1977).

One of the first extensive blood chemistry evaluations of cattle was performed by Anderson et al. (1930) utilizing dairy breeds in the research herd at the Pennsylvania State College. The authors were interested in examining the effects of age, breed and sex on profile variability. Compton Metabolic Profile Test (CMPT) was devised to assist in diagnosis of clinical problems of dairy herds by comparing blood composition of selected animals with normal values (Payne et al., 1970). The original CMPT involved the analysis of a set of 11 variables in blood samples taken from three groups of seven cows, one near peak of lactation, another in mid-lactation, and the other antepartum. Means of variables were calculated for each lactational group in each herd, and this set of means constitutes the metabolic profile (Rowlands and Pocock, 1976). Payne et al. (1974) indicated that developing a metabolic profile may be useful in detecting herds suffering from subclinical production diseases or indicate which items of food intake are inadequate for production. Secondly, it might help in selection of superior stock which are able to maintain homeostasis in spite of poor dietary conditions and high production. Thirdly, it might be possible to predict potential future production from the metabolic profile of a young animal. Collins (1978) discussed the need for a rapid, economical, and reliable means of diagnosing the cause(s) for substandard performance of beef animals. The development of analytical instruments that rapidly and automatically perform

multiple analyses on a large number of blood samples has reduced the cost significantly. Many types of automated equipment are available today for accurate, rapid and economical analysis of blood. Examples of the autoanalyzers which perform multiple blood component assays on a single sample are sequential multiple analyzers (SMA) and sequential multiple analyzer with computer (SMAC). The SMAC is available in many human diagnostic laboratories for obtaining up to 25 tests results from a single sample. According to scientific literature, the majority of blood components in cattle fall within the ranges found for human blood (Collins, 1978).

According to the literature, many research studies have used the Bos taurus as experimental unit, and Bos taurus is different in many respects (blood profile values included) from the Bos indicus and thus represents a relative new and dynamic subject for research. Some blood profile work has been done using the Bos indicus cattle (Kunkel et al., 1953, Fletcher et al., 1956; Howes et al., 1961; Kirk and Davis, 1970, Stont et al., 1976; Hogg, 1981; Collins, 1978; Tucker, 1978).

Serum Metabolites

Enzyme Components

Lactic dehydrogenase (LDH)

The enzyme LDH is involved in hydrogen transfer and catalyzes the oxidation of L-lactate to pyruvate with the mediation of NAD as hydrogen acceptor. Kachmar and Moss (1976) indicated that LDH levels are much higher in tissues than serum and any damage to tissues will create elevated serum LDH levels. LDH_1 through LDH_5 can be used as diagnostic tools for determining more specifically which tissue or

organ has been damaged. Wilkinson (1969) observed that isoenzymes LDH_4 and LDH_5, which are electrophoretically slow, increased dramatically in patients with liver disease. While not tissue specific, total LDH activity has been found to give an indication of potential problems, especially if consideration is given to nutritional or environmental conditions. Begin et al. (1977) observed that total LDH was elevated in mastitis conditions due to udder epithelial and interstitial cells being damaged in the inflammation process. Normal LDH concentrations are affected by breed (Boyd, 1962; Keller, 1974), decreased with age and increased in cases of liver necrosis (Keller, 1974). However, Ford and Boyd (1960) noted elevated enzyme concentrations in ketotic cows.

Serum glutamic-oxalacetic transaminase (SGOT)

This enzyme is widely distributed in tissues of all species and especially concentrated in the heart, the muscle and the liver (Cornelius et al., 1959; Wrobiewski and LaDue, 1955). Elevated SGOT was found in calves suffering from tissue necrosis and white muscle disease. Also, Blincoe and Dye (1958) observed increases of the enzyme in cattle and sheep suffering from white muscle disease. Liver SGOT concentrations were found elevated in ketotic cows (Ford and Boyd, 1960). Krebs (1966) concluded that the enzyme is normally elevated during gluconeogenesis and amino acid catabolism. It was reported that the level of the enzyme can be elevated by factors such as age (Muilen, 1973) and liver flukes.

Alkaline phosphatase (ALP)

This enzyme is present in all tissues of the body, especially in cell membranes (Kachmar and Moss, 1976). The exact function of this

enzyme is not known but it appears to facilitate transfer of metabolites across cell membranes, is associated with lipid transport and is important in the calcification process in bone synthesis. It was observed that ALP decreases with age, the concentration of ALP in young clinically normal animals is higher than older ones (Allcroft and Folley, 1941; Alexander et al., 1958). Cornelius et al. (1959) confirmed the effect of age and he added that ALP level became slightly elevated in pregnancy and was fairly constant for any one animal. Breed and nutrition have been reported as a source of variability in normal values. Kunkel et al. (1953), who compared cattle of Brahman and European breeds, and Allcroft and Folley (1941), who worked with Hereford cows and dairy Shorthorns, reported the variability due to age. Healy and McInnes (1975) observed the highest ALP level was in lambs fed above maintenance and the lowest ALP level value was in lambs fed below maintenance.

Serum glutamic-pyruvic transaminase (SGPT)

Kachmar and Moss (1976) reported that SGPT catalyzes the interconversion of amino acids and alpha-oxoacids by transfer of amino group. SGPT is more or less liver specific and normally would be elevated in liver diseases, but one should be cautioned against making conclusive diagnosis of liver disease solely on the basis of increased SGPT. Kearney et al. (1967) indicated SGPT concentration may have been due entirely to the fluke migration. Mullen (1973) detected significant increases in SGPT of calves monitored from 7 days to 11 months of age.

Glucose, total cholesterol, and triglycerides

Because little glucose is derived from dietary sources in ruminants, its homeostasis depends on regulation of gluconeogenesis and hepatic glucose. The liver maintained a normal blood glucose, through a complex hormonal control system involving glucagon, epinephrine, and glucocorticoids which respond to different stimuli (Bergman, 1973). Elevated blood glucose was observed in cows and calves under intense feeding regimens (Payne et al., 1974) and low blood glucose was associated with energy deficient diets (Payne et al., 1970). It was observed that blood glucose level was lower in adult ruminants (Anderson et al., 1980, Dickerstaffe et al., 1974).

Cholesterol is considered the most important steroid in animal tissue. Cholesterol may account for 90% of total serum lipids (Raphael et al., 1973). Triglycerides, whether derived from fatty acids or synthesized from carbohydrates and amino acids, represent a body fat depot (Maynard and Loosli, 1969). Brahman cattle were found to be lower in triglycerides than British cattle (O'Kelly, 1986a, 1986b). In a study to determine whether age or nutrition caused serum cholesterol fluctuation, Carrel and Hamilton (1973) concluded that diet was the primary factor.

Nitrogenous Components

Total protein (TP)

Serum TP can be divided into two major fractions - albumins and globulins. It was reported that serum TP had a relatively fast turnover rate and seemed to be in dynamic equilibrium with the intracellular amino acid pool (Hassan and Roussel, 1976). Therefore, a long term shortage of dietary N is required to induce a decrease in

TP concentration of serum. Dunlop and Dickson (1955) reported that serum TP showed a steady but slight decrease throughout gestation. The increase in levels of serum TP was documented by Gartner et al. (1968) and Hewett (1974). O'Kelly (1972) observed variation due to breed and, in 1973, he found British calves tended to have slightly higher serum TP levels than Brahman calves. Serum TP can easily be affected by diet. Nomani and Evans (1972) observed a positive response of serum TP to increased dietary nitrogen.

Albumin fraction

Albumin is synthesized by the liver and conditions which impede liver functions would be expected to affect albumin production. Belyea et al. (1975) reported a positive relationship between serum albumin of prepartalent cows and protein intake. Hewett (1974), in a study involving dairy cattle, reported decreases of serum albumin concentrations with increasing age. Dimopoullos (1971) cited values for calves less than 3 months to be 3.7 ± 1.1 mg/100 ml.

Globulin fraction

Globulins can be split into alpha, beta, and gamma fractions by electrophoresis. Alpha and beta globulins are synthesized by the liver, however, gamma globulins, often referred to as immunoglobulins, are synthesized and secreted by plasma cells in lymph nodes, bone marrow, and spleen (Grant and Kachmar, 1976). Serum globulins are elevated in a number of tissue disorders - hepatitis (Cornelius, 1971), hyperlipoproteinemia (Grant and Kachmar, 1976), and fascioliasis (Anderson et al., 1977). It was generally agreed that serum globulin levels of young animals is lower than those of adults and this increase with age may be due to a rise in the gamma globulin

fraction. It was observed that the globulin fraction of serum was highly negatively correlated with serum albumin (Kitchenham and Rowlands, 1976) and was not affected by diet (Bedrak et al., 1969). Barnatt et al. (1973) found little variation in globulin levels of serum through a physiological cycle of one year except at parturition and onset of lactation.

Blood urea nitrogen (BUN)

Blood urea nitrogen is a metabolic end product of protein catabolism. High levels of dietary N result in a proportional increase in ruminal ammonia and BUN. Preston and Pfander (1963) concluded that BUN was a sensitive indicator of protein adequacy and, if protein is held constant while energy intake increases, BUN concentration decreases. It was observed that the variability in BUN was associated with breed and age (Anderson et al., 1930; Kitchenham and Rowlands, 1976). Greatorex (1965) determined that BUN levels were higher in calves than in cows and in open cows than in those pregnant. The author also found a significant difference between breeds.

Mineral Status of Animals

Essential Major Mineral Elements

Calcium and phosphorus

Underwood (1966) suggested that Ca and P are best considered together because of their close association in the performance of their major functions and their nutritional interdependance and relationship to vitamin D. Calcium and P depend on vitamin D and Mg for proper utilization. Phosphorus deficiency is predominantly a condition of grazing ruminants, especially cattle, whereas Ca deficiency is more a problem of hand-fed animals, especially pigs and

poultry (Underwood, 1981). Calcium deficiency does not occur frequently in cattle because of the long period that calves are on milk and the high roughage diets that are ordinarily fed to pregnant and lactating cows. Calcium deficiency are characterized by rickets and osteomalacia (Thompson, 1978).

Due to highly regulated control mechanisms, most animals will deplete a considerable portion of bone Ca reserves before most other functions are impaired by lack of Ca. On the other hand, P deficiency very quickly impairs performance measures including growth, reproduction and milk synthesis (W.J. Miller, 1981). For grazing cattle, probably the most prevalent mineral element deficiency throughout the world is lack of P (McDowell, 1976). Improved growth and reproductive performance in cattle with P supplementation and pasture fertilization has been reported from a number of countries (Fick et al., 1978; McDowell et al., 1984)

Phosphorus is a factor in the metabolism of almost all nutrients because of its role in enzyme activity. The 20% P found in soft tissues has vital metabolic roles in carbohydrate metabolism, in the formation of hexosephosphate, creatinine phosphate and adenylic acid, and in protein metabolism where it is present in nucleoproteins and phosphoproteins (Conrad, 1978)

Calcium is the most abundant mineral element found in the animal body, with about 99% of it found in bones and teeth and the remaining 1% widely distributed in various soft tissues of the body (Smith, 1965). Therefore, Ca requirements are highest during periods of rapid skeletal development and during periods of lactation since milk contains approximately .12% Ca (Conrad, 1978). Calcium deficiency is

rare in grazing cattle, with the exception of cows producing large quantities of milk or those on acid, sandy or organic soils in the humid areas where the herbage consists mainly of quick growing grasses and is devoid of legume species (Underwood, 1966).

Vitamin D is required for normal absorption of Ca and P. Severe deficiency of Ca and P causes inadequate calcification of the growing skeleton and other deviation in bone development, also often caused by deficiency of vitamin D. In mature cattle, excessive demineralization of the skeleton, called osteoporosis, may result (CMN, 1973).

Calcium and phosphorus in blood serum

Underwood (1966) indicated that heifers and young cows having a more efficient mechanism for mobilizing Ca from the bones were more resistant to milk fever than older cows. Normal concentration of plasma Ca is 9 to 12 mg/100 ml; the lower values occur in newly calved, highly productive cows. In cows with milk fever, Ca values fall markedly even if the ration contains sufficient Ca. However, rations severely deficient in Ca resulted in Ca deficiency particularly in young cattle (CMN, 1973). Underwood (1966) considered Ca levels in blood as a good indicator of Ca status of grazing animals and suggested 9-11 mg Ca/100 ml of blood plasma as the normal level. Cunha et al (1964) suggested that, under Florida conditions, mean Ca levels below 8 mg per 100 ml of plasma were suggestive of a Ca deficiency.

Parturiant hypocalcemia is a metabolic disease associated with parturition and the initiation of lactation. It is characterized by hypocalcemia, hypophosphatemia and hypomagnesemia (Hibbs, 1950). Recently, the cause of parturient paresis was attributed to metabolism

of vitamin D (DeLuca, 1974). A failure of the kidneys to biosynthesize sufficient 1, 25$(OH)_2$D was suggested as a possible explanation for parturient hypocalcemia (Fraser and Kobicek, 1970). Lebdosoekojo (1977) observed that serum Ca levels were greatly affected by season, however, the effect due to mineral supplementation was not significant. Levels were higher ($P < .01$) at the beginning of the rainy season than the dry season (10.12 and 9.41 mg/100 ml, respectively).

Benzie et al. (1955) reported a good correlation between blood plasma Ca contents and dietary Ca. Underwood (1966) indicated that there is a negative correlation between serum P and Ca in deficient animals, with Ca increasing until values of 13 to 14 mg/100 ml of serum are reached. Dietary P supplementation increased plasma P levels, but depressed plasma Ca concentrations, conversely, high dietary Ca tended to reduce plasma P levels (Chicco et al., 1973).

The most sensitive and earliest biochemical measure of P deficiency is a reduction in serum inorganic P (Underwood, 1966). Values consistently below 4.5 mg/100 ml in poultry, cattle and sheep are indicative of P deficiency. Since the homeostatic or physiological mechanisms regulating Ca are more effective than for P or most other minerals (Underwood, 1966, W.J. Miller, 1970), the CNN (1973) did not consider serum inorganic P to be sufficiently sensitive to recommend it in diagnosing problems with cattle, and they indicated that forage analyses give earlier and more detailed information. Normal concentration of blood inorganic P is 4 to 8 mg/100 ml (Hemingway, 1969). Bone mineral is readily mobilized to maintain a constant level of serum Ca, but less readily mobilized to maintain

serum P. Therefore, a low serum inorganic P level is an early indicator of P deficiency (Duncan, 1958). Knox et al. (1941) indicated that inorganic P in blood plasma appears to be closely related to P intake.

Phosphorus deficiency is a serious problem in Florida. Becker et al. (1933b) found levels of blood plasma P were in the range of .83 to 4.83 mg/100 ml from cattle showing signs indicative of P deficiency. More recently, Shirley et al. (1968) reported average plasma P values of 4.3 mg/100 ml in cows grazing on non-fertilized sandy soils. The importance of Ca:P ratio is widely recognized, but this ratio is less critical with ruminant animals than in simple stomach animals. Phosphorus contributes about 1% of the total animal body weight and 20% of it is distributed throughout the body in every living cell, being involved in almost all metabolic reactions (Church, 1971).

Variation in the blood plasma P may be due to many factors. Shirley et al. (1968) reported significant seasonal variations in plasma and forage P concentrations with values being higher during summer and fall than during winter. Gartner et al. (1965) reported higher plasma inorganic P from excited animals than from drug-tranquilized, spleenectomized and normally rested animals. Standish et al. (1971) indicated that feeding high levels of Fe on the order of 1000 ppm to steers resulted in decreased P concentrations in blood plasma. Daynell et al. (1973) reported an increase of inorganic P when the serum was separated from the whole blood three hours after blood collection. Reed et al. (1974) reported that serum inorganic P levels were increased by supplementing cattle with bone meal, but Ca and Mg levels were depressed. McAdam and O'Dell (1962) studied

mineral profiles of blood plasma of lactating dairy cows and found that, at parturition, plasma P concentration decreased for all animals except young cows fed plain salt. Plasma P remained fairly constant for animals on each treatment (salt vs. complete minerals) through lactation, with only minor elevation and depression. Inorganic plasma P percentage was highest in first lactation and declined with subsequent lactations. Season of calving had a significant effect on plasma inorganic P (Forar et al., 1982).

Bone calcium and phosphorus

Abnormalities of bones and teeth can occur at any age. Withdrawal of Ca and P from the bones occurs normally and regularly in dairy cows at the height of lactation and in hens during intensive egg-laying, even when intakes are otherwise adequate. Withdrawal of minerals during periods of inadequate intake does not take place equally from different parts of the skeleton. The spongy bones, ribs, vertebrae and sternum, which are the lowest in ash, are the first to be affected. The essential change is a reduction in the total mineral content of the bones, with little alteration in the proportions of the minerals in the remaining ash (Underwood, 1981). Benzie et al. (1955) indicated that the axial skeleton and ribs were depleted and rehabilitated more rapidly than long bones; therefore, changes in nutrient intake are better detected from the axial skeleton and ribs. Feeding growing animals a moderately P-deficient diet for longer periods (14-18 months) showed a depression effect on the total ash concentration of the ribs and vertebrae when compared with similar bone from animals on the same diet supplemented with phosphate (Stewart, 1934, quoted by Underwood, 1981).

The ash content of bone is commonly used as a measure of the status of Ca and P nutrition (Maynard and Loosli, 1969). The authors indicated that in mammals the bone is made of approximately 36% Ca, 17% P and .8% Mg, based on dry fat-free bone. An experiment conducted by Peducasse (1982) in tropical areas of Bolivia to determine the mineral status of beef cattle during the dry season found deficient levels of Ca (37.6%) and P (17.6%) in bones (as % bone ash). Ninety-six percent of the bone samples had Ca levels lower than 34% bone ash and 45% of the samples were less than 17% P. In a study of grazing cattle in Panama, Ammerman et al. (1974) observed the average values of bone (dry fat free) ash of 60.5-67.7%, 37.6-38.2% and 17.6-18.1% for ash, Ca and P levels, respectively. Kiatoko (1976) obtained a value of 48.2 to 55.6% bone ash on a dry fat free basis in cattle grazing on Costa Rican farms which had less than .33% P in the forages. Mendes (1977) found bone ash Ca ranged from 36.96 to 38.45% and ash P from 15.13 to 16.64%.

Cohen (1973b) correlated P concentration in pasture, blood, hair and bone. He found a high correlation (r = .97) between P in the pasture and in dry fat free ribs. Sousa et al. (1975) found a positive correlation between rib ash P and soil Ca, forage Ca, rib ash Ca and soil P. The author also found that rib bone ash means were 37.7 and 15.5 for Ca and P, respectively, during dry season and 37.6 and 15.0 for Ca and P, respectively, during the wet season. The levels of rib bone ash Ca are considered normal, but P is below the normal level and considered as borderline to deficient. The mean rib ash P during the dry season was higher than during the wet season,

even when forage P levels were low, suggesting a higher requirement during the wet season compared to the dry season.

The percenteges of bone ash and bone as P are greatly affected by dietary P levels. Bayley et al. (1975) reported bone ash and breaking strength were increased by P supplementation at levels of .32 and .48%. Rosa (1980) found that P supplementation produced a 3.9% increase ($P < .01$) in bone ash. Conversely, excess dietary Al effected bone ash by causing a 2.3% reduction ($P < .01$) in that parameter. Cohen (1973a) studied the effect of P supplementation on the P content of blood and on P and Ca contents of hair and bone of grazing steers, and concluded that measurement of bone P and Ca provided the most sensitive indication of the P and Ca status of beef cattle and that while P supplementation has no effect on liveweight of beef steers its effect on the mineralization of bone tissue may still justify its use, particularly in areas where poor bone development and lameness occur.

Phosphorus in feces

The main route of P excretion is in feces. Tillman and Brethour (1958) reported that 95 percent of ingested phosphorus was excreted via feces. Researchers confirmed that urinary P excretion was very low as compared to fecal excretion (Ammerman et al., 1957). However, when an excess of parathyroid hormone was injected, urinary P excretions increased while fecal output decreased.

Any changes in the dietary P levels will be reflected in the output of the fecal P. It was indicated that the correlation between dietary P and daily fecal excretion was highly significant (Cohen, 1974; Winks et al., 1977). The authors observed that as P content of

forages decreased during the dry season, fecal P concentration likewise decreased.

Calcium, phosphorus and magnesium in hair

There has been considerable interest recently in the use of hair as an indicator of the mineral status of animals. Evidence indicates that certain trace mineral deficiencies can be detected by hair analysis (Werner and Anke, 1960, cited by Wysocki and Klett, 1971), but the relationship between Ca and P contents of hair and the level of the diet has received limited attention (Stippel et al., 1964). O'Mary et al. (1969) found a significant variation in the concentration of Ca, Mg and P in hair due to hair color, age of animal, and season of the year. These three elements were higher in red hair than in white hair. Calcium and Mg collected in August were higher than those collected in March. Phosphorus, however, showed no season variation. Calcium contents were higher in calves than in cows. Kiatoko et al. (1982) reported differences ($P < .05$) in hair P contents, which were higher in the dry season than wet season (218 vs 104 ppm) and higher in heifers than mature cows. Wysocki and Klett (1971) studied hair as an indicator of Ca and P status of ponies and they indicated that Ca and P in the diet are not correlated with the amounts in the hair. Also, they reported that hair analyses for Ca and P as a basis for establishing the nutritional status are of little use in making feeding recommendations. The authors also found a season trend in the concentration of Ca and P in hair. Calcium and P levels in hair were highest in spring and fall and were lowest in the winter. The concentration of these minerals tended to follow the activity of the hair growth with higher levels during the most active

periods. Anke (1967) indicated that there was a difference in mineral contents of hair depending on the site on the animal body where hair samples were collected

Peteva-Vancheva and Ilciva (1978) reported that, under Bulgarian conditions, Ca and P nutrition were considered optimum for cattle when hair contained 400 ppm and 200 to 230 ppm P. Hair Ca below 300 ppm and P below 180 ppm were suggested as dietary deficiencies.

Magnesium status of animal tissues

Magnesium is an essential macroelement in the nutrition of ruminants which is present in the body in the proportion of approximately .05%. About 60% of the total Mg is found in the skeleton, with the remainder in the soft tissue (Viana, 1978). Rook and Storry (1962) reported that about 30% of skeletal Mg in young animals can be mobilized under conditions of Mg deprivation, while in adult animals, only 2% of bone Mg can be used for physiological needs.

According to Walker and Vallee (1964), Mg takes part in about eighty enzymatic reactions. Mg is vitally involved in the metabolism of carbohydrates and lipids as a catalyst of a wide array of enzymes which require these elements for optimum activity (Walker, 1965). According to these functions, it is not surprising that Mg deficiency in animals is manifested clinically in a wide range of disorders, which include retarded growth, hyperirritability and tetany, peripheral vasodilation, anorexia, muscular incoordination and convulsions (Underwood, 1981). The most important practical Mg deficiency problem in farm animals is the condition, largely confined to lactating cows, known as grass tetany (Underwood, 1966).

The NRC (1976) indicates that, for growing and finishing steers and heifers, the Mg requirement is .04 to .10% of diet dry matter. O'Kelley and Fontenot (1969) reported that levels of 18, 19 and 16% of the rations of lactating beef cattle on a dry matter basis, in the first, second and third phases of lactation, are necessary to maintain a level of 2 mg of mg/100 ml of blood serum. Underwood (1966) suggested that level of .07% Mg in diet will be adequate to satisfy the minimum requirements for the growth of cattle and sheep and the range of .10 to .17% Mg are the minimum levels for cows and ewes in lactation.

There are many factors and interactions which may effect the level of Mg in animal tissues. In ruminants, a physiological Mg deficiency frequently occurs in adult animals when turned into fresh pasture during spring and autumn. According to Newton et al. (1972), high K ingestion results in a decrease in apparent Mg absorption in sheep. Young lambs received diets containing .10% and 4.9% of $KHCO_3$ but which were equal in Ca and P. The average absorption of Mg was 49.1% and 26.4% for the animals fed the low and high levels of K, respectively. Watson et al. (1966) reported that high N fertilization of forages has been shown to increase crude protein content of the forage and has adversely affected Mg utilization in cattle grazing the herbage. Scotte et al. (1971) indicated that administration by drenching of KCl and citrate or transeconitase would produce tetany in a high percentage of experimental cattle.

Magnesium in blood serum

The Netherlands Committee on Mineral Nutrition (CMN, 1973) suggested that in healthy animals with adequate Mg nutrition, normal

serum Mg could vary between 2 and 3.5 mg per 100 ml. Values below 2 mg/100 ml were found when animals were in negative Mg balance. Cunha et al. (1964) suggested 2.5 mg/100 ml of serum as a normal level in cattle. On the other hand, Underwood (1966) considered the normal level of serum Mg in cattle to be 1.8 to 3.2 mg/100 ml. According to the Committee on Mineral Nutrition (CMN, 1973), the Mg status in the animal is best assessed from Mg levels in blood and urine. Serum Mg levels of 1 to 2 mg/100 ml are considered deficient and a level of less than 1.0 mg/100 ml indicates danger of tetany. Cunha et al. (1964) reported that calves showing clinical signs of tetany contained levels as low as 1 mg/100 ml of Mg blood serum. Kemp (1960) observed a significant positive correlation between serum and forage Mg concentrations. High dietary Ca depressed Mg content in bone and plasma and decreased Mg utilization; however, high Mg in the diet reduced plasma Ca (Chicco et al., 1973). The authors indicated that dietary P had little effect on Mg utilization, and positive correlation was found between dietary Mg and either plasma or bone Mg.

Bone ash magnesium

Taylor (1959) found that calves can mobilize Mg reserves in the bone relatively more easily than mature animals. Furthermore, Smith (1959) reported Mg was more readily removed from cancellous than from compact bones.

Blaxter and Sharman (1955) indicated that Mg concentrations in rib bone of cattle range from .67 to .70% in hypomagnesemia and levels of rib ash Mg decreased to a range of .19 to .35%. Lebedomskoje (1960) reported rib ash Mg concentrations from young bulls under grazing conditions in a range of .6 to .73%. Rib bone ash Mg levels

during the wet and dry seasons were .46 and .48, respectively. The lower level of rib bone ash Mg during the wet season is probably due to higher requirements when animals are rapidly gaining weight (Sousa, 1978). A significant negative correlation was found between bone ash concentration of Mg and the length of time animals were fed a Mg-deficient diet (Harrington, 1975).

Calcium and magnesium in feces

There is evidence that Mg absorption in ruminants occurs mostly in the lower part of small intestine while the endogenous Mg is secreted into the proximal end of the small intestine (Ferry et al., 1967). If this is true, then we would expect Mg to have a good efficiency of recycling. Hutton et al. (1965) reported that 80 percent of dietary Mg was excreted in feces while only 12 percent was recovered in urine. Hansard et al. (1952) found that Ca was mainly excreted via feces. Brenner (1964) indicated that an increase in Ca intake, decreased Ca absorption and increased fecal excretion. Calcium retention can be increased by feeding high-nitrogen forages and vitamin D supplementation to low-nitrogen diets (Stillings et al., 1964). Verdaris and Evans (1976) reported that high pH in feed mixtures reduced Ca absorption, while an acid diet reduced fecal Ca output. The authors also indicated that high Ca diets resulted in high fecal Mg excretion.

Sodium, potassium and chloride

It is convenient to consider Na, K and Cl together because of the broad similarities in their functions and requirements in the animal body and their interactions with each other, and because Na and Cl are associated in the form of common salt (Underwood, 1981). Sodium

requirements for growing and finishing steers and heifers have been reported to be about .06% of diet dry matter (NRC, 1976). Due to limited storage, animals need to receive a regular supply of NaCl. Any excess consumed is rapidly excreted in the urine. Animals reacted to low dietary Na by largely eliminating urinary losses (Loosli, 1978). The author also found that even after prolonged severe deficiency, neither blood levels of Na nor the amounts secreted in the milk decrease. Thus, lactating animals suffer most from the lack of salt in the diet. Salt deficiency results in an abnormal appetite which is manifested by the animals chewing and licking various objects. Prolonged deficiency results in a lack of appetite, unthrifty appearance and decreased production (NRC, 1976). Sodium deficiency in grazing animals has been induced by heavy K fertilization, which depressed Na uptake by grasses (Loosli, 1978). Sodium constitutes about .2% of the body and occurs primarily in the extracellular fluids (Maynard and Loosli, 1969). On the other hand, Cl is found both in the intra- and extracellular fluids, making up two-thirds of the acid ions in the body (Maynard and Loosli, 1971). Pearson and Wolzak (1982) indicated that the normal routes of Na excretion are the urine, sweat and feces. The urinary excretion is the most important mechanism of Na elimination and is determined by the balance between Na filtered from blood in the glomerulus and that actively reabsorbed from the renal tubules.

Potassium requirements of beef cattle have been reported to be .6 to .8% of diet dry matter (NRC, 1976). Excessive levels of K have been found to interfere with Mg absorption and, also with high levels

of P, to increase the incidence of phosphatic urinary calculi (NRC, 1976)

In contrast to Na, K is present primarily inside the cells. The blood cells contain approximately 25 times as much K as is present in the plasma. Muscle and nerve cells are also very high in K (Thompson, 1978). Saliva is the best criterion for Na and K assessment, because the body reacts to their deficiency long before clinical signs appear. Normal values in saliva are 3.3 ± .3 Na and .3 ± .1 g/l K (CNN, 1973). Gomide et al. (1969) noted that a low forage K content may be a critical factor in poor performance of cattle, particularly during the dry season. Plasma Na and fecal Na are not a reliable index of Na status (Kemp, 1964). On the other hand, depressed plasma K is characteristic in K deficiency. Reduced milk K and increased hematocrit readings are observed during K depletion (Pradhan and Hemken, 1968).

Essential Trace Mineral Elements

Copper, molybdenum and iron

Besides the function of the Fe in hemoglobin formation, it has been reported the Fe is important in electron transport mechanism in cells and as a component of several heme enzyme systems (Church and Pond, 1975). According to McDowell et al. (1978), Fe is the most deficient mineral for young swine and man, yet in grazing cattle, Fe deficiency is unlikely to occur except in circumstances involving blood loss, parasitic infestation or disease. Approximately 25% of total body Fe is stored as ferritin and hemosiderin in the liver, spleen and other tissues (Thomas, 1970). In all species, Fe deficiency results in a hypochromic, microcytic anemia with low serum

Fe, increased total serum Fe binding capacity (TIBC) and a decreased transferrin saturation (Underwood, 1971) The development of Fe deficiency anemia in suckling domestic animals was due to low level of Fe contained in milk. It developed more rapidly in suckling pigs than in lambs or calves because of the much greater growth rate of the pig during the suckling period (Miller, 1981). Beef cattle require Fe, but the minimum requirement has not been established (NRC, 1976). The suggested requirement for beef cattle is 10 to 30 ppm (NRC, 1976)

The body has a limited ability to excrete Fe. Most of the Fe eliminated from the body is via the feces, but this consists primarily of unabsorbed food Fe. Losses from urine and sweat are minor. Even the loss of Fe in milk by high-producing dairy cows is not great because of the low level of Fe in milk, ~5 ppm (E.R. Miller, 1981).

Standish et al. (1971) indicated that high dietary levels of Fe as ferrous sulfate resulted in reduced performance and changes in mineral composition of steer tissues. Average daily feed intake and average daily gain were depressed by as little as 400 ppm Compounds such as ferrous salphate and ferric citrate are more available to cattle than is ferric oxide or iron phytate (Ammerman et al., 1967, Bremner and Dalgarno, 1973) Levels of dietary Fe exceeding 1000 ppm for growing cattle have generally reduced growth rate and plasma inorganic P levels (E.R. Miller, 1981). Molybdenum can interfere with Cu metabolism at well below the 5 ppm Mo or more that has generally been used under experimental conditions or that occurs in molybdenosis (Underwood, 1979). The Cu-Mo ratio is very important in the metabolism of both elements. The critical ratio is debatable, but it was indicated that a ratio below 2 would be expected to cause

conditioned Cu deficiency in cattle (Miltimore and Mason, 1971). Underwood (1979) suggested that the critical ratio is even higher than 2:1, perhaps nearer 4:1.

In many areas of the world, Cu deficiency is a major problem for grazing cattle (Underwood, 1981; CMN, 1973). Young and growing animals have a higher Cu requirement and, therefore, a higher deficiency incidence than mature animals (Underwood, 1966). Forages grown on organic soils of Florida are high in Mo and their consumption can result in molybdenosis or hypocuprosis in grazing cattle (Becker et al., 1965). Copper retention was shown to be dependent upon the Mo status of the diet and the limiting effect of Mo was shown, in turn, to depend upon the inorganic sulfate status of the diet and of the animal (Dick, 1956, quoted by Underwood, 1971).

Due to various existing interactions, the livestock requirement for Mo has not been adequately determined (W.J. Miller, 1975). Molybdenum toxicity occurs in cattle grazing pastures which are characterized by Mo concentration ranging from 20 to 100 ppm, but not in cattle grazing normal pastures containing 3 to 5 ppm or less Mo (Underwood, 1971).

A primary Mo deficiency in commercially fed farm animals or in grazing livestock has never been reported. Such a deficiency seems unlikely because of the low Mo requirements of animals (Underwood, 1981). The criteria most commonly used for assessing Cu deficiency are the concentrations of Cu in the liver and blood. Using Cu levels in diet or pasture has limited diagnostic value, unless other elements with which Cu interacts, particularly Mo and S, are also determined (Underwood, 1981).

Copper, molybdenum, and iron in liver

Generally, blood analysis may give a good indication of the macrominerals Ca, P and Mg. However, macroelements are too low in blood and their determination is often subject to some analytical errors. Since liver is the metabolic center of minerals in the body, it is useful in estimating the mineral status of livestock (Hoyazoglu et al., 1972). The liver is the main storage organ of the body for Cu, so that liver Cu concentrations would be expected to provide a useful index of the Cu status of the animal. Among domestic livestock, liver Cu values are consistently high in healthy sheep, cattle and ducks, with a normal range of 100-400 ng/g on the dry basis (Underwood, 1981). In cattle, there is little variation between young and mature animals, although sometimes young animals may have higher Cu concentrations than adults (Church, 1971). According to the Netherland Committee on Mineral Nutrition (CMN, 1973), normal liver Cu should be in the order of 200 ppm for yearling cattle and 150 ppm for heifers and cows. Cunha et al. (1964) suggested that, under Florida conditions, liver Cu levels in cattle with good Cu nutrition status should normally be between 100 to 300 ppm on a dry matter basis and values of 75 ppm could be considered as marginal, while values below 25 ppm of Cu were often accompanied by severe clinical signs of Cu deficiency.

Liver Cu concentrations are influenced by various dietetic factors. In sheep and cattle, liver Cu concentrations can be reduced by increasing Mo and S dietary levels. High intakes of Zn reduce the absorption of Cu and Fe as well as their retention (Underwood, 1971). Standish et al. (1971) indicated that dietary Fe depressed absorption

of Cu and, in Cu deficient cattle, liver Fe values reach as high as 13939 ppm dry matter basis, while Cu concentrations were as low as 5 ppm (Mitidieri et al., 1959). Sulfur is important in this interaction between Cu and Mo. More recently, Suttle (1975) felt that total sulfur rather than sulfate alone was more important in the alteration of liver Cu. Ward (1978) indicated that in the liver Mo inhibited the oxidation of sulfides to sulfate, resulting in the accumulation of sulfides in the liver which may not be biologically available. Rosa (1980) studied the interrelationship between Cu, Zn and Fe using Florida native mature wethers and found that there was a main effect of high dietary Cu on liver Cu concentration represented by an increase ($P < .01$) of hepatic Cu from 341 to 850 ppm. Liver Cu was also affected by an interaction ($P < .05$) of Fe and Zn.

Hartmans (1974) found no correlation between the incidence of Cu deficiency in cattle and the Cu status of soil and pasture grazed by these animals. However, at low Cu nutrition status, the author found a positive relationship between blood plasma and liver Cu and the Cu concentration in feed. The author suggested that liver Cu indicates Cu deficiency earlier than blood, thus, liver is the best indicator of Cu status of grazing animals.

The normal tissue Mo is present in low concentrations and the differences among species are small, but it is possible to raise the levels in the liver and bone by increasing dietary Mo intake (Underwood, 1977). Liver normally contains 2 to 4 ppm Mo on a dry matter basis in the majority of species. This level can be elevated to 25 to 30 ppm by increasing dietary Mo intake. The levels rapidly

return to normal when the administration of extra Mo ceases (Underwood, 1971).

In contrast to Cu, one-half to three-fourths of the total body Mo of sheep is situated in the skeleton (Underwood, 1971). The author concluded that the Mo level in the liver of an animal, therefore, gives little indication of its dietary Mo status and is of limited diagnostic value for this reason. Molybdenum toxicity leads to bone abnormalities, but it has no effect on the Ca and P content of the bone (Hidiroglou et al., 1982). Molybdenum toxicosis usually occurs on pastures containing 5 to 20 ppm Mo on a dry matter basis, but when dietary Cu intake is abnormally low or dietary sulfate intake is high, Mo intake as low as 1 to 2 ppm may be toxic (Pope, 1975). Toxicosis is the major concern in Mo nutrition. Values even less than 10 ppm dietary Mo in ruminants effect Cu metabolism (Suttle, 1980). The author indicated that clinical signs of Mo toxicosis are similar to those of Cu deficiency. According to Underwood (1977), Mo toxicity occurs in cattle grazing pastures with 20 to 100 ppm Mo, but not in cattle grazing normal pasture with 3 to 5 ppm Mo or less. Chronic Cu poisoning is the result of continual ingestion of Cu in concentrations that exceed the maximum safe level of 20 ppm for sheep. This crisis is characterized by the sudden onset of severe hemolysis and hemoglobinemia associated with jaundice, liver and kidney damage (Brakley et al., 1982).

Underwood (1977) indicated that liver is one of the main Fe storage organs. Iron in the liver is mostly in the form of two nonheme compounds, ferritin and hemosiderin. The author also indicated that, in cattle with nutritional siderosis and sheep suffering from Cu

or Co deficiency, most of the Fe was present as hemosiderin. Hartley et al. (1969) reported that the approximate normal level of Fe in cattle liver ranges from 160 to 300 ppm on a dry matter basis. Cunha et al. (1964) indicated 200 to 300 ppm as the normal level of Fe in cattle liver.

A close relationship was reported between Cu and Fe in liver (Boyazoglu, 1973; Cunha et al., 1964). Alfero and Heaton (1974) found increased liver Fe in rats during periods of a Cu deficiency with Fe being deposited mostly in the mitochondria.

Copper and zinc in feces

Available information indicates that feces are the main means of excretion of both Cu and Zn, while excretion of these elements is reported to be low (Comar et al., 1949; Smith et al., 1964). Any change in the dietary levels of Mo and S will effect the fecal Cu output. Huisingh et al. (1973) indicated that, in the presence of Mo and S, Cu becomes less available due to the formation in the rumen of insoluble cupric molybdate and sulfide which are later excreted in the feces.

Studies supporting the concept that the body homeostatic control of Zn is strong and is related to body need for Zn were reviewed by W.J. Miller et al. (1966) and Robinson et al. (1973), the authors indicated that, in the absence of interfering substances, high fecal excretion may denote a high Zn intake, while animals on low Zn intake have usually a reduced fecal excretion. According to W.J. Miller et al. (1970), factors such as Ca, Cd, Mg, P, Cu, EDTA, and phytic acid may have an inhibiting effect on Zn absorption resulting in higher Zn excretion in the feces.

Copper and zinc in hair

Kellaway et al. (1978) investigated the possibility of using hair to help diagnose hypocuprosis. Liver, blood and hair samples were collected from steers fed diets containing different levels of Mo and S. Progressive changes in liver levels of Cu were closely paralleled by changes in Cu levels in hair and plasma. The authors concluded that levels in hair are a useful diagnostic aid in detecting hypocuprosis. Hair provides an integrated record of Cu availability during its periods of growth and, thus, may be preferred to blood plasma which represents only a spot sample in time.

Signs of Cu deficiency in animals include achromotrichia (lack of hair pigmentation) and impaired keratinization of hair leading to changes in the growth and appearance of hair (Underwood, 1977). The author also found that alopecia (loss of hair) may develop in animals suffering from Zn deficiency.

O'Mary et al. (1970) investigated the influence of dietary Cu on the pigmentation of hair and concentration of Cu, Na, Zn, Ca, P, Mg, Fe and K in hair of calves. The authors found that the highest level of dietary Cu (71.1 ppm) did not produce toxic effects during an 112 day period. An increase in dietary Cu significantly increased the levels of Cu in hair, but had no significant effect on the levels of Na, Zn, Ca, Mg, P, Fe and K. They concluded that white hair appears to offer most promise for determining relative previous nutritional status since color reflects mineral composition. However, Anke (1966) found no significant increase of Cu in hair following an increase of dietary Cu. On the other hand, there was a significant increase of Zn in hair following an increase of dietary Zn. Similarly, Ott (1965)

fonnd that increasing dietary Zn resulted in increased Zn concentrations of hair Dietary Ca, however, was found to reduce hair Zn concentration

O'Mary et al. (1969) stndied the effect of irrediation, age, season, and color on mineral composition of Hereford cattle hair, and the authors concluded that highly significant differences appeared between seasons In August, the hair contained greater amounts of Na, Cu, Ca, Mg, Mn and K when compared to samples taken in March Samples taken in March had a higher content of Fe. They also found that red hair contained a greater percent of ash and more Ca, P, Mg, Mn, Fe and K, but less Cu than the white hair, and the hair from calves contained a greater concentration of Na, Ca, Cn and K, but less Mn and Fe than did that from cows. Hidiroglou and Spur (1975) obtained higher hair Zn values in the summer months than in winter According to the authors, the seasonal hair Zn variation may be due to the lowered forage Zn contents during winter.

Anke (1967) reported average Cu concentrations of cattle hair on the order of 7.8 ppm Hair Zn concentration has been shown to be an useful indicator of animal Zn status. Ott (1965) obtained hair Zn concentration values on the order of 137 ppm in beef cattle fed 100 ppm Zn.

Perry et al (1976b) studied human hair as indicators of exposure to environmental pollutents; they concluded that the study of the distribution of elemental concentrations along human hair (actually in ratios to Zn) can be used as a method to identify the pollutants in the area Snch measurements give information on exposure of subjects

to different pollutants, and the history of the exposure manifest in the variations of concentrations along the hair.

Copper, zinc, hemoglobin, and hematocrit in blood

The concentrations of Cu in liver, blood and hair have all been employed as indicators of Cu deficiency (Underwood, 1975). Underwood (1977) has summarized literature dealing with the forms and distributions of Cu in blood. He reported that Cu in blood plasma occurs in two main forms: ceruloplasmin and direct reacting Cu. Ceruloplasmin is an alpha-globulin containing 7 atoms of Cu/mol. It is a firmly bound blue Cu which represents about 90% of the total plasma Cu, and plays a role in Fe utilization and iron saturation of transferrin in the plasma.

According to Cunha et al. (1964), normal Cu concentration of whole blood in the healthy mature bovine is 75 to 100 ug/100 ml. Hartsman (1974) reported that plasma Cu was related to liver Cu only when dietary Cu intake was low. At high Cu intake, neither liver Cu nor Cu nutrition status could be predicted from plasma Cu. The CMN (1973) indicated that plasma Cu concentrations of 60 to 75 ug/100 ml are considered slightly deficient, while levels below 40 ug/100 ml are clearly deficient.

Zinc had been established as essential for laboratory animals in the 1930s but, even in 1966, relatively little was known about its requirement and metabolism in cattle (W.J. Miller, 1981). Since 1960, Zn nutrition and metabolism in cattle have been the subject of considerable research. Zinc is widely distributed throughout the body and plays an essential role in many body processes. It is present in many enzyme systems involved with the metabolism of feed constituents

(Cunha, 1981). The primary role of Zn in animal nutrition appears to lie in the fundamental process of cell replication and gene expression and to involve nucleic acid and protein metabolism.

Animals are quite tolerant of excessive dietary Zn. The first effects are lower feed consumption and reduced weight gains. Excessive Zn interferes with the metabolism of some other trace elements, especially Cu and Fe. Except where massive amounts of Zn are fed, either intentionally or accidentally, it appears unlikely that too much Zn should be a practical problem (W.J. Miller, 1981).

According to the CNN (1973), Zn status of animals could be assessed by Zn concentration in plasma, with values of 60 to 140 ug/100 ml indicating a normal Zn status. Mills et al. (1967) indicated that 10 to 14 ppm of Zn in a semipurified diet were sufficient to maintain normal plasma levels between 80 and 120 ug/100 ml in calves. Zinc levels in the plasma respond very rapidly to the alteration in the diet. They added that plasma Zn fell to less than 40 ug/100 ml. Studies of excess Zn levels indicate that lactating dairy cows fed 1275 ppm of Zn in the diet did not experience reduced performance. Growing cattle fed 900 ppm Zn exhibited decreased weight gains and feed efficiency (Cunha, 1981). Spais and Papsteriadis (1974) found that, under Greek conditions, cattle with serious Zn deficiency signs had plasma Zn values of 40 to 60 ug/100 ml compared to plasma Zn concentrations of 60 to 100 ug/100 ml in animals with adequate Zn nutrition. Variations in plasma Zn may be due to hyperthermia and ketosis which are lower than in normal cows. Cows suffering from mastitis infection had higher Zn concentrations than healthy cows (Wegner et al., 1973).

The hemetocrit or packed cell volume (PCV) is expressed as the percent volume of packed cells in whole blood after centrifugation at 3000 rpm per 30 minutes (Dukes, 1970). The same author also indicated that, in normal animals, hematocrit values were directly related to the erythrocyte count and hemoglobin content. In healthy cattle, hemoglobin may range from 11 to 12 g/100 ml (Underwood, 1977) and hematocrit values may very from 38 to 45 percent with a mean value of 40 percent.

Several factors may cause variations in the levels of hemoglobin and hematocrit. Excited animals have higher values (Gertner et al., 1965; Dukes, 1970), which may be caused by the release of catecholamines and mobilization of erythrocytes from the spleen into the circulatory system (Dukes, 1970). Zinc deficiency in baby pigs resulted in increased hematocrit values (E.R. Miller et al., 1968). Shirley et al. (1962) indicated a seasonal variation of hemoglobin concentration in cattle with highest values being observed in summer and fall, while the lowest values were found in winter. Hemetocrit values obtained on the same experiment, however, seemed to be higher in winter than in summer or fall.

Zinc in liver

Underwood (1977) indicated that liver was the major organ involved in Zn metabolism. In the liver, one-sixth of the Zn may be firmly bound to protein and cannot be displaced by dialysis or by EDTA. The remaining five-sixths of liver Zn are exchangeable Zn ions and consist of Zn enzymes in which Zn is less tightly bound to imidazole or sulfhydryl groups of the protein.

Zinc content of tissues other than plasma decreases quite slowly, if at all, when a Zn-deficient diet is fed (W.J. Miller, 1969). Zinc content in a number of calf tissues was increased several fold when 600 ppm supplemental Zn was fed and before any clinical signs of toxicity appeared (W.J. Miller et al., 1970). Underwood (1962) suggested that liver Zn values above 125 ppm should be considered as the normal value for cattle.

Factors which reduce Zn absorption in the gastrointestinal tract have also been indicated to reduce Zn concentration in liver. Standish et al. (1971) reported that Fe fed to cattle at high levels of 400 to 1600 ppm tended to decrease liver Zn concentrations, moreover, Cd, Ca, Mg, P and Cu, as well as chelating agents such as EDTA, vitamin D and phytic acid, influence Zn absorption and metabolism (W.J. Miller, 1972). The binding pattern of liver Zn, like the total Zn concentration, was unaltered in Zn deficiency; therefore, for detecting mineral status of animals, Zn in liver is not a good indicator.

Manganese and cobalt

The Mn requirement for growth of cattle is low, usually 1 to 10 ppm of dietary dry matter. With high levels of dietary Ca and P, the Mn requirement is apparently somewhat elevated. Most roughages contain more than 30 ppm (NRC, 1976). Cows receiving lower Mn rations showed delayed estrus and were slower to conceive. However, for maximum fertility, Rojas et al. (1965) concluded that the diets of cows should contain more than 16 ppm Mn.

According to CMN (1973), there is as yet no practical criterion for assessing the Mn status of animals. Liver biopsy seems the most

promising. Analysis of hair is doubtful, since results are difficult to interpret. Decreased bone and blood alkaline phosphatase have been observed in Mn deficiency (Underwood, 1966). However, alkaline phosphatase is affected by many conditions and, thus, is not a good biochemical measurement of Mn deficiency (W.J. Miller and Stake, 1974). Thomas (1970) indicated that interrelationships of Mn with other dietary factors, such as organic compounds, Ca, P, Mg and Fe, have been known to occur. Highatt (1959) suggested that Ca and P affect the utilization of Mn required for enzyme systems essential for establishing and maintaining pregnancy.

Blood Mn values are extremely variable, reflecting both individual variability and analytical inadequacies. Blood concentration substantially below .02 ug Mn/ml suggests the possibility of a dietary deficiency in sheep and cattle (Hidiroglou, 1975). Mn is distributed throughout the body and is found in higher concentrations in bone, liver, kidney and pancreas (McDowell et al., 1978). Milk and milk products are lower in this metal due to the generally very low content of Mn in cow's milk (20-40 mg/l), according to Underwood (1981).

The Co requirement of beef cattle is between .05 and .1 ppm (dry basis). Cattle on pastures having Co levels in this range are free from deficiency signs (IRC, 1976). Similarly, Ammerman (1970) and Underwood (1971) found the minimum Co requirement of dairy cattle to be about .10 ppm. Since the required level is more than the amount contained in many forages and some concentrates, supplemental Co is needed under many practical situations. Forage samples from 'salt sick" areas in Florida were analyzed and compared to healthy ranges

(Becker et al., 1965) and the following results were obtained: the average of the respective groups was .02 ppm Co from the "salt sick" areas and .063 ppm on a dry matter basis in wiregrass from healthy ranges.

A severe Co deficiency causes appetite failure which is due, at least in part, to the animal's inability to metabolize propionate. This is followed by the onset of anemia and, eventually, extreme emaciation. The activity of the enzyme methyltransferase is depressed in the liver of the vitamin B_{12}-deficient sheep, with possible impaired nitrogen retention (Gawthorne and Smith, 1974, cited by Underwood, 1981). Conrad (1978) indicated that liver Co was responsive to dietary Co intake and could be used for diagnostic purposes of Co deficiency in grazing cattle and sheep. Since Co deficiency is an area problem, knowledge of the soil (Co, pH, etc.) is very useful. Conrad (1978) indicated that, if the herbage consistently contains less than .08 ppm Co, a deficiency can be predicted with a relatively high degree of confidence. Winter et al. (1977) reported that the occurrence of Co deficiency in grazing animals was related to the presence of sandy soils low in Co content and to the seasonal variation of Co concentrations in forage. The authors added that some forages of the region may contain .126 ppm Co in the wet season, while this level may decrease to .005 ppm near the end of the dry season.

Manganese and cobalt in liver

Hartmans (1974) indicated that a Mn value of 9 ppm in the liver of cattle may be considered as marginal. A series of studies reported by Underwood (1977) support the idea that normal liver Mn

concentration in sheep and cattle could range from 8 to 10 ppm. McDowell et al. (1978) suggested that a Mn deficiency can be best detected by the combination of liver (less than 6 ppm Mn) and diet (less than 20 to 40 ppm) analyses. Howes and Oyer (1971) obtained higher liver Mn levels (614.7 ± 195.9) in calves fed 14.5 ppm Mn from birth compared to the liver Mn concentration of 6.36 ± .6 ppm in calves fed the control diet.

The bone, liver, kidney, pancreas, and pituitary gland normally carry higher Mn concentrations (1-3 ppm on fresh basis) than do other organs. The storage capacity of the liver for Mn is limited, compared with the great capacity of this organ to accumulate Fe and Cu (Underwood, 1971). Several researchers note only a small change in tissue Mn level (two-fold) has been brought about with a 200-fold increase in dietary Mn (Thomas, 1970). According to Carter et al. (1974), it appears that liver Mn changes readily up to a certain level (about double normal) and then resists further changes.

Dickson and Pond (1974) reported liver Co concentrations of .06 to .38 ppm in apparently healthy animals, while cattle dying from Co toxicity had liver Co concentration ranging from 20 to 69 ppm. Cunha et al. (1964) suggested that normal values of Co in the liver of cattle should be .2 ppm, while levels of .07 ppm are indicative of a borderline, and .04 ppm of a severe deficiency. Mendez (1977) reported mean liver Co values ranging from .040 to .691 ppm in the wet season and .124 to .730 ppm in the dry season. Lebdoseekoje (1980) obtained mean liver Co concentration on the order of .17 ppm in cattle grazing native pasture and fed common salt compared to liver Co values of .34 ppm in animals grazing the same native pasture but supplemented

with complete mineral supplement. McDowell et al. (1982), in cattle of Florida, found that liver Co concentration was 1.06 ppm in cows and .88 ppm in heifers where forage Co levels varied from .09 to .12 in the wet season and from .12 to .26 ppm during the dry season. Lea (1963) observed a positive relationship between dietary and livar Co concentrations. The author found that animals grazing Co deficient pastures showed liver Co concentrations of less than .02 ppm, animals or mild Co deficient pastnres had liver Co valnes in the range of .02 to .06, while animals grazing adequate pastures showed liver Co concentrations of .10 to .30 ppm. Reduced ruminant liver stores of Co and vitamin B_{12} are indicative of a diatary Co deficiency and storage levels are frequently nsed to determine the Co status of ruminants (Ammerman, 1981)

Manganese in hair

For animals which are not completely in confinement, the hair growth is mainly dependent on the season. Seasonal effects are noted by several investigators by determining the flnctuations in mineral levels throughont tha year (Hidiroglou and Spnr, 1975). It is not yet established how much of this season influence can be explained by changes in metabolism of the animal, bnt it is beyond any donbt that thare is a large indirect effect thrnugh the diat. The decrease and increase corresponded to the difference ir diet levels which was lower in the winter feed than in pasture (Hidiroglou and Spur, 1975) Only iron deviated from this pattern with a maximnm concentration in March/April (Franzmann et al., 1975).

Stenger and Loeck (1973) observed larga variations in Mn contents in the hair of cattle depending on the slte of the body where hair

samples were collected. Hair samples from the tail showed Mn values in the range of 80 to 3.76 ppm, while hair samples from the forehead had 1.52 to 2.82 ppm. These authors concluded that hair was not a good indicator of Mn status of grazing animals. Hair Mn from grazing cattle was more related to the Mn content of the forage pasture than liver, bone, blood or any other tissue (Anke, 1967). O'Mary et al. (1969) obtained hair Mn variations of 6 to 104 ppm with Mn being higher in red hair than in white hair, and higher in August than in March.

Selenium status of animal tissues

Selenium was first recognized as an essential trace mineral in 1957 when it was found to prevent liver necrosis in rats. Subsequently, Se deficiency effecting a number of systems and producing a variety of lesions has been observed in swine, poultry, horses, sheep, and cattle (Hidiroglou, 1980). In cattle, white muscle disease is the most commonly recognized problem. "Blind Staggers" and "alkali disease' were identified as manifestations of acute and chronic Se poisoning, respectively (Underwood, 1981).

The prophylectic efficacy of Se and vitamin E was tested under field conditions. Herds initially were chosen because of a chronic problem with retained placenta which could not be related to a known etiological factor. Incidence of retained placenta was reduced from a mean of 51.2% in control cows to 8.8 for animals injected with Se and vitamin E. It was concluded that a single 20 day prepartum injection of 50 mg of sodium selenite and 680 IU of alpha tocopherol acetate is an effective prophylactic for prevention of retained placenta (Julien and Conrad, 1976). Segerson et al. (1976) studied the role of

Se/vitamin E in fertilization of bovine ova maintained on either adequate or inadequate nutrition. Fertilization of ova was 100% in those females receiving supplemental Se/vitamin E and an adequate plane of nutrition. Interaction between plane of nutrition and Se/vitamin E was significant for percent fertility.

Dietary or injectable vitamin E and Se independently enhanced the immune response. The combination of both nutrients, provided either in the diet or via injection, resulted in a further increase in hemagglutination titers suggesting an additive effect. Dietary sources of these nutrients resulted in greater serum and tissue levels than did injections (Peplowski et al., 1981). A metabolic interrelationship between Se, vitamin E and S containing amino acids exists at the cellular level. Selenium functions in the cytosol through glutathione peroxidase (GSH-PX). Glutathione peroxidase uses glutathione, a tripeptide with S, to reduce hydrogen peroxide and organic hydroperoxides to less harmful products (Hidiroglou, 1980).

The Se requirement of beef cattle depends on the amount of vitamin E in the diet, but it is approximately in the range of .05 to .10 ppm of dry diet. Cows grazing pastures with less than this quantity of Se produce calves with nutritional muscular dystrophy. Selenium toxicity may occur when cattle consume feed for extended periods containing 10 to 30 ppm Se on a dry matter basis (NRC, 1976).

As discussed earlier, failure in reproductive functions and a high incidence of retained placentas have been associated with Se deficient rations. In grazing animals, three distinct Se deficiency syndromes have been described: "white muscle disease" (WMD) in

newborn, unthriftiness, and poor growth rates which may occur in the absence of any other recognizable disease.

Perry et al. (1976a) conducted an experiment to study the effect of supplemental Se at levels of 0, .1, .2 or .4 mg/kg to a finishing beef cattle diet containing .08 mg/kg. An increased rate of weight gain was obtained from adding .1 mg Se/kg; however, .2 or .4 mg/kg resulted in a significant depression in rate of gain, indicating that the range between sub-optimal and possible growth-depressing levels of dietary Se for beef cattle may be quite narrow. The authors also indicated that tissue concentration of Se was increased as the daily intake of Se was increased, regardless of tissue sampled.

More recently, Perry et al. (1976) indicated calf serum Se levels at birth reflected maternal treatments, being higher in calves from cows fed 5 mg/day than in calves from unsupplemented cows ($P < .01$). The authors also observed that calf liver Se was higher ($P < .01$) for calves from the 5 mg cows than for calves from all cows that had received other treatments. Elevated calf blood serum Se levels, from cows fed the higher Se levels, indicated Se does cross the placental membrane. Whanger et al. (1977) conducted an experiment with sheep fed purified diets to determine the effects of Se and vitamin E on incidence of WMD and blood components. All lambs reaching 6 weeks of age in the group receiving no vitamin E or Se developed WMD lesions whereas only a few lambs in either Se or vitamin treatment groups developed these lesions. Plasma activities of creatinine phosphokinase, lactic dehydrogenase and glutamic oxaloacetic transaminase were significantly elevated in lambs receiving no vitamin E or Se. The authors also added that, under the conditions of their

study and the results obtained, vitamin E alone was more effective in the prevention of WMD than Se alone.

The effects of vitamin E and Se deficiency have been postulated to result from loss of membrane integrity which leads to cell death. Addition of polyunsetureted fetty acids to the diet tends to exacerbate these deficiency defects whereas synthetic antioxidants, in many cases, will alleviate the signs of vitamin E and Se deficiency. Se was also classified as an antioxidant due to its ability to prevent a number of vitamin deficiency diseases (Sunde and Hoekstra, 1980).

Acute Se poisoning is most often associated with consumption of Se accumulator plants which may contain from 100 to over 9000 ppm Se and emit a strong characteristic odor. The existence of accumulator plants indicates seleniferous areas or Se toxic regions (Underwood, 1966).

Selenium and vitamin E in blood

The main functional form of Se in animal tissues was identified as a thioenzyme, glutathione peroxidase (GSH-PX)(Rotruck et al., 1973). This selenoenzyme contains four moles of Se per mole of enzyme (Hoekstra et al., 1973, Hoffman et al., 1978). Low blood Se is always found in Se-deficient conditions. A direct relationship between blood GSH-PX activity and Se concentrations has been established (Hidiroglou, 1980). Total plasma Se has been reported to respond to dietary Se. Perry et al. (1976a) reported that supplementation of steers with 0, .01, .2 and .4 ppm Se resulted in a respective increase of plasma Se from .024 ppm in control animals to .073 ppm in animals fed .4 ppm Se. Segerson and Johnson (1980) studied the effect of Se and reproductive function in yearling Angus

bulls and found pooled Se at 21-day intervals averaged .01 and .08 ($P < .001$) for control and supplemented bulls, respectively. They concluded that injections of supplemental Se increased both serum and tissue concentrations of this element. No clinical signs of Se deficiency were observed in control bulls even though serum Se concentration was as low as .01 ppm. In contrast, the serum Se concentration ($\geq$ ppm) for treated bulls was comparable to serum levels considered adequate for various aspects of reproductive performance in beef and dairy cows.

Selenium in liver, feces and hair

Underwood (1977) indicated that liver and kidney contains the highest concentration of Se. Selenium in liver and hair is very responsive to dietary Se. Underwood (1979) reported that the Se concentration in the tissues of animals reflects the dietary Se level over a wide range from deficient to toxic intakes. Selenium levels of .5 ppm in the kidney cortex and .05 ppm (fresh basis) in the liver are considered to be indicative of marginal Se deficiency in sheep and levels below .25 and .02 ppm, respectively, to be indicative of marked Se deficiency in this species. McDowell et al. (1978) indicated that normal Se levels in the liver of cattle are usually above .25 to .5 ppm on a dry matter basis, while values on the order of 5 to 15 ppm are suggestive of an excessive Se intake. Ammerman et al. (1980) found that liver concentrations were higher ($P < .05$) for calves from cows fed linseed meal calculated to provide a natural Se adequate level than they were for calves from cows fed the natural, Se-deficient soybean meal supplement.

McDowell et el. (1982), in Florida, reported liver Se concentrations were below critical levels (25 ppm) in 32.2 and 38.8% of the samples in the wet and dry seasons, respectively. Like forage and soil Se, liver and hair Se concentrations were deficient. Much of the Se in tissues is highly labile and transfer of animals from seleniferous to nonseleniferous diets is followed by rapid and then slow loss of Se from the tissues via bile, urine and/or expired air. Concentration in tissues tends to reflect dietary Se concentrations particularly when provided by natural dietary ingredient as compared to selenate of selenite (NRC, 1980). McDowell et al. (1977) suggested that hepatic, renal, cortical and blood Se concentrations of .26, 2.5 and .1 ppm (dry basis), respectively, were determined to be critical levels for pigs below which clinical illness or lesions of Se-vitamin E deficiency could be expected.

Hidiroglou et al. (1965) reported a relationship between hair Se concentration and the occurrence of white muscle disease in cattle. In their studies, cows with hair Se levels between .06 and .25 ppm (dry matter) produced calves with white muscle disease, while cows with hair Se higher than .25 ppm had normal calves. The Se content in urine, blood and hair similarly reflected dietary intakes, but were highly variable. Thompson et al. (1981) indicated that Se concentration in plasma and liver provides the best indicator of current dietary Se intake in cattle and erythrocyte GSH-PX activity is suitable as an alternative test for the routine diagnosis of Se deficiency. Also, there is a clear relationship (r = .97) between blood Se concentration and erythrocyte GSH-PX activity (Thompson et al., 1981).

hair from normal cows generally contains 1-4 ppm Se compared with 10-30 ppm for cattle on selaniferous range (Underwood, 1981). Perry et al. (1976a) reported hair Se concentrations on the order of .30, .49, .58, and .50 ppm in steers fed 0, .10, .20, and .40 ppm Se, respectively, for 113 days.

Lopez et al. (1969) suggested that the kidney has high ability to excrete Se. Wright and Bell (1966) recovered 4.6 percent Se in feces and 29 percent in urine in sheep given I.V. doses of Se, and 66 percent in feces with 4.6 percent in urine after an oral dose of Se.

The concentration of Se in milk varies greatly with the Se intake of the animal. Perry et al. (1977) observed milk Se concentrations ranging from 7 to 33 ppb when cows were supplemented with linseed meal. Perry et al. (1977) studied milk Se from feeding small amounts of Se (0, 2, or 5 mg/day) to mature cows 90 days postpartum through approximately 7 mo postpartum. The authors indicated that the average for each treatment over time showed milk from cows fed 5 mg added Se per day had more ($P < .05$) Se in milk than did those fed no supplemental Se. However, there were no significant differences in Se in the milk from the two lower amounts of added dietary Se (1 or 2 mg).

Ammerman et al. (1980) found that milk Se concentrations, which range from 7 to 20 ppb, were higher ($P < .01$) for cows on the linseed meal plus Se treatment than for those receiving no Se supplementation

CHAPTER III
MINERAL STATUS OF GRAZING BEEF CATTLE
IN THE WARM CLIMATE REGION OF FLORIDA

Introduction

In many tropical and warm climate regions, mineral deficiencies, imbalances and excesses are a great detriment to the cattle industry (McDowell, 1976). Mineral deficiencies or imbalances in soils and forages have long been held responsible for low production and reproduction problems among Florida beef cattle. Recently, nutrient status of beef cattle ranches from four soil regions of Florida was determined (Kiatoko et al., 1982). Phosphorus, Se, and Zn deficiencies were present in all of the four regions studied with protein, vitamin A, K, Mg, Na, Cu, and Co deficiencies found in certain regions and related to season of the year. Mineral deficiencies or toxicities in grazing livestock can be predicted by the use of a systematic mapping survey technique or by regional reconnaissance (McDowell, 1976). The objectives of the present study were to evaluate the initial mineral status of soils, forages, and beef cattle tissues in the sandy loam soils in the warm climate region of Central Florida, before receiving mineral supplementation.

Materials and Methods

Liver biopsy, blood, soil, and forage samples were collected from a ranch in Central Florida in May, 1980. The soil (Entisol) was sandy and well drained and pastures were exclusively bermudagrass (Cynodon

dactylon) and bahiagrass (Paspalum notatnm). Fertilization of pastures consisted of 341 kg of 15% (N), 5% (P_2O_5), and 10% (K_2O) per hectare. From four separate pastures, a total of 12 soil and 16 forage samples were collected. Liver and blood samples were collected from 36 Brahman cows (four to eight years old) during early pregnancy. Free choice mineral supplements containing typical macro- and microelements (except selenium) were available and contained the following percentages: Ca (18.0), P (6.0), NaCl (26.0), Fe (1.0), Cu (.15), Co (.03), Mn (.02), Mg (.60) and Zn (.04).

Procedures for collection, preparation, and analysis of liver biopsy, blood serum, and forage samples for mineral concentrations have been described (Fick et al., 1979). Liver biopsy samples (.2 to .6 g dry basis) were pre-ashed on a hot plate with concentrated nitric acid and then ashed overnight in a muffle furnace at 550° C. Ash was solubilized by digestion, first with 50% nitric acid, secondly with 10% nitric acid, and finally with distilled water. Calcium, Mg, Cu, and Zn in serum and Fe, Zn, Cu, and Mn in liver were analyzed by flame atomic absorption spectrophotometry using a Perkin-Elmer Model 306 (Perkin-Elmer, 1973). Liver Mo and Co were determined with an atomic absorption spectrophotometer equipped with a graphite furnace and D_2 corrector (Perkin-Elmer, 1973). Serum P was determined by the colorimetric technique described by Harris and Popat (1954). Serum and liver Se were determined by a modification of the fluorometric method (Whetter and Ullrey, 1978). Forage samples were analyzed for the same minerals determined for liver and serum plus K and Na as previously described.

Soil samples were collected in the same pastures where forages were sampled using a stainless steel tube at a depth of 10 to 15 cm. Soils were analyzed by the method described by Mitchell and Rhue (1979) for the same minerals analyzed in forage excluding Se, Co and Mo. Soil pH was determined using a 1:2 soil-to-water ratio in a standard glass electrode and a calomel reference electrode. Soil organic matter was determined by the Walkley-Black procedure (Allison, 1965) and P with the Technicon Autoanalyzer II (Technicon Industrial Systems, 1976).

The word "critical" is used in this paper to note a concentration in forages below (or above in case of excesses) the quantity estimated to be the requirement (NRC, 1976) of cattle. Total consumption per day, not concentration in forage, would be used to determine the true adequacy of a mineral element. Critical animal tissue concentrations were considered to be below or above values associated with specific clinical signs as reported in the literature.

Results and Discussion

Soil and forage mineral composition data are presented in Tables 1 and 2. On the basis of ARC (1980) and NRC (1976) requirements in cattle rations for concentrations of mineral elements, the forages consumed in expected quantities were deficient in P, Fe, Se and Zn. Of the 16 total forage samples analyzed for P, 68.8% were below the critical level (< 25%) suggested by McDowell and Conrad (1977). However, all the soil samples analyzed were above the critical level of P (< 5.0 ppm) as suggested by Breland (1976). Mean forage P concentrations in Florida have been reported to be low, especially during the dry season, with Becker et al. (1966) reporting a decrease

TABLE 1. SOIL MINERAL ELEMENT CONCENTRATIONS (DRY BASIS), pH AND ORGANIC MATTER AS RELATED TO CRITICAL LEVELS

Mineral	Soil concentration		Critical[c] level	% samples below critical level
	Mean[a]	S.D.[b]		
Calcium (ppm)	403.5	154.6	71	0
Phosphorus (ppm)	76.2	28.7	5	0
Potassium (ppm)	76.3	82.6	30	0
Sodium (ppm)	16.3	6.1		
Magnesium (ppm)	70.5	5.8	9.1	0
Copper (ppm)	.63	.55	1	75
Iron (ppm)	16.3	4.4	4.5	0
Manganese (ppm)	3.34	.82	5	100
Zinc (ppm)	1.41	1.34	6	100
Organic matter (%)	1.63	.34		
pH	6.30	.35		

[a]Represents four pastures with three soil samples collected each for total of 12

[b]Standard deviation.

[c]Breland, 1976, Warncke and Robertson, 1976, Cox and Kamprath, 1972, Blue et al., 1982, Gammon, 1976

TABLE 2. FORAGE MINERAL CONCENTRATIONS (DRY BASIS) AS RELATED TO CRITICAL LEVELS

Mineral	Forage concentration		Critical[c] level	% samples below critical level
	Mean[a]	S.D.[b]		
Calcium (%)	.34	.14	.3	43.8
Phosphorus (%)	.22	.05	.25	68.8
Magnesium (%)	.22	.06	.2	31.3
Potassium (%)	1.43	.27	.6	0
Sodium (%)	.09	.04	.06	0
Cobalt (ppm)	.16	.04	.1	25
Copper (ppm)	15.1	13.3	10	37.5
Iron (ppm)	29.2	12.9	30	68.8
Manganese (ppm)	56.3	25.1	30	6.2
Molybdenum (ppm)	23	.02	6 (*)	0
Selenium (ppm)	.04	.02	1	100
Zinc (ppm)	18.7	6.4	30	100

[a] Represents four pastures with four samples each for total of 16

[b] Standard deviation

[c] McDowell and Conrad, 1977.

(*) Max Tolerable level

in level of forage P from .23% in April to .11% in July. Soil Ca averaged 403.5 ppm which was markedly higher than the range of 72 to 140 ppm reported by Breland (1976) for Florida soils. Nevertheless, 43.8% of the forages provided less than the requirement of .3% (NRC, 1976) for grazing cattle. Mean soil Mg was 76.2 ppm, much higher than the critical level of 9.1 ppm reported by Breland (1976). Forage Mg averaged .22% which was higher than .18% recommended by the NRC (1976). All samples analyzed for K were above critical concentrations in soils (30 ppm, Warncke and Robertson, 1976) and forages (.6%, McDowell and Conrad, 1977). A recent report (Kiatoko et al., 1982) indicated that Central Florida forage K concentrations were adequate during the wet season (1.05%) but were lower (.56%) during the dry season. All forages were adequate in Na when compared with the NRC Na requirement of .06%. Many tropical regions have reported low forage Na concentrations (McDowell, 1976).

Generally, forages were within the normal limits for Mo and Mn. However, all soil Mn concentrations were below the critical level of 5.0 ppm as suggested by Gammon (1976). A relatively large percentage of forages were borderline to deficient in concentrations of Fe (69%), Co (25%), and Cu (38%). Seventy-five per cent of soil Cu concentrations were likewise below the reported critical level of 1 ppm (Gammon, 1976), but none of the soil Fe concentrations was below the critical level of 4.5 ppm reported by Cox and Kamprath (1972).

Forage trace elements most severely deficient were Se and Zn with all forages containing less than the critical concentrations of .1 and 30 ppm, respectively. All soil Zn concentrations were below the critical level of 6 ppm Zn (Blue et al., 1982). In recent years, Zn

deficiencies have been reported in cattle with one of the earliest reports for cattle grazing forages containing 18 to 42 ppm in Guyana (Legg and Sears, 1960). Mean forage Se of .04 ppm was less than one half the requirement of .1 ppm (NRC, 1976). Selenium deficiency as evidenced by white muscle disease in calves has been reported in the Florida locations of Branford, Gainesville and Newchule (L. R. McDowell, pers. comm.).

Mean cattle liver and blood serum concentrations are presented in Table 3. More information about the initial period (period 1) are presented in Tables 8, 15, 16, 17, and 20. Mean serum Ca was 10.4 mg/100 ml with only 5.7% of the 30 serum samples below the critical level of 8 mg/100 ml as suggested by Cunha et al. (1964). Of the total serum samples analyzed for P, 40% were below the critical level of 4.5 mg/100 ml suggested by Underwood (1966). Considering the low levels of forage P, a higher proportion of critical cattle plasma P concentrations (4.5 mg/100 ml) were expected. Two explanations for the relatively high serum P levels were (1) use of P in mineral supplements available to cattle and (2) less than optimum conditions for the sampling and processing of blood for P analyses. Factors that elevate plasma minerals particularly P (Fick et al., 1976) including stress, exercise, hemolysis, temperature, and plasma separation time were difficult to control during the experiment.

Of 26 liver samples, 12% were below the critical level of 5 ppm Mn (McDowell and Conrad, 1977) which compares to 6.2 and 100% of forages and soils, respectively, below critical concentrations. Liver and ovaries are thought to be organs most likely to show detectable variations in Mn concentration with differing dietary Mn levels (Egan,

TABLE 3. MINERAL CONCENTRATIONS OF BLOOD SERUM AND LIVER AS RELATED TO CRITICAL LEVELS.

Mineral	Mean[a]	S.D.[b]	Critical[c] level	% samples below critical level
Blood serum				
Calcium, mg/100 ml	10.4	2.6	8	6.7
Phosphorus, mg/100 ml	6.2	1.8	4.6	40
Magnesium, mg/100 ml	2.43	.32	2	3.3
Copper, ug/ml	.80	.02	.65	0
Selenium, ug/ml	.006	.003	.03	100
Zinc, ug/ml	.84	.03	.8	46.7
Liver (ppm, dry basis)				
Copper	228.6	80.5	75	17.6
Cobalt	.44	.21	.05	0
Iron	384.0	88.7	180	11.7
Manganese	9.9	2.7	6	12.4
Molybdenum	2.76	.56	5	0
Selenium	.16	.02	.25	100
Zinc	107.3	27.4	84	28.2

[a]Number of observations is 30 serum and 26 liver.

[b]Standard deviation.

[c]McDowell, 1976, McDowell and Conrad, 1977.

1975). Only 11.7% of liver Fe concentrations were low (< 180 ppm) in contrast to 68.8% of forages low in this element. Although one quarter of forage Co concentrations were deficient (< .1 ppm), all liver Co levels were adequate, above the critical level of .05 ppm (Underwood, 1977). Large quantities of Co are included in Florida free choice mineral supplements further explaining high liver Co concentrations.

All serum and 82.4% of liver samples analyzed for Cu were above the critical levels of 0.65 ug/ml and 75 ppm, respectively, as suggested by McDowell and Conrad (1977). Liver Cu levels are more reliable than blood levels in assessing the Cu status of the animal (Doyle and Spaulding, 1978). In a previous Florida study (McDowell et al., 1982), 36.4% of all liver samples were low (< 75 ppm) in Cu during the wet season and 20.2% had low concentrations during the dry season. With the exception of P and possibly Co, Cu is the most limiting mineral for grazing cattle in tropical developing countries (McDowell, 1976).

In agreement with deficient Zn concentrations in both soils and forages, 47% of the serum and 88.2% of liver samples analyzed for Zn were below the critical levels of 8 ug/ml and 84 ppm, respectively, recommended by McDowell and Conrad (1977). McDowell (1976) has indicated that serum Zn concentrations are a better indicator in cattle than level of this element in hepatic tissue.

All the serum and liver Se concentrations were below suggested critical levels of .03 ng/ml (Underwood, 1977) and .25 ppm (McDowell, 1976), respectively. Both serum and liver are reported to be good indicators of the selenium status of cattle.

Summary

An experiment was conducted to determine the mineral status of purebred Brahman beaf cattle grazing bermudagrass-bahiagrass pastures grown on sandy, well drained soils in Central Florida. Soil, forage, blood serum, and liver tissue concentrations of Ca, K, Na, Mg, Mn and Co were generally adequate. Sixty-nine per cent of forages and 40% of serum samples were deficient in P. Seventy-five per cent of soils, 38% of forages, and 18% of liver samples were deficient in Cu. Sixty-nine per cent of forage samples were low, less than 30 ppm, in Fe. All samples of forage, liver and serum were deficient in Se. Likewise, all soil and forage samples and 47 and 88% of serum and liver samples, respectively, were deficient in Zn. Mineral elements most likely deficient and needed in supplements for grazing cattle on sandy, well drained soils in warm climate regions of Central Florida are P, Cu, Se and Zn.

CHAPTER IV
RELATIVE COMPOSITION OF MACRO ELEMENTS
IN SOIL, DIET AND TISSUES OF BRAHMAN CATTLE

Introduction

The majority of Florida soils have developed from relatively coarse-textured, highly weathered materials. In general, these soils are acid and low in natural fertility (Yuan, 1963, Zelanzy and Fiskell, 1971). Soil acidity may cause multiple nutrient deficiencies from inhibition of root growth (Adams and Pearson, 1967, Kamprath, 1972; Black, 1968). The problem associated with high Al and Mn can be eliminated in surface soils by liming to pH 5.5 (Bine and Dantzman, 1977). According to Bine (1974), P is probably the most deficient nutrient in acid soils. Therefore, crop establishment and development in tropical acid soils is often impossible without P application (Bine, 1969).

Kirk et al. (1970) indicated that in Florida the critical forage period was usually from December to March (winter). This is because of the slow growth rate of pasture, periodic frost, and low mineral content of forages during this period. Native Florida pastures have been reported to have low dry matter yields and be deficient in certain plant nutrients. Among macro nutrients studied, Ca and P were reported to be deficient in cattle grazing on acid soils (Underwood, 1966, Becker et al., 1969). Burning of pastures as a solution to increase Ca and P levels in forages was found to be effective only for

short durations, and followed by a drastic monthly decrease of forage Ca and P concentrations (Becker et al., 1965).

For grazing cattle, probably the most prevalent mineral element deficiency throughout the world is lack of P (McDowell, 1976). Improved growth and reproductive performance in cattle with P supplementation and pasture fertilization has been reported from a number of warm climate countries (Fick et al., 1978, McDowell et al., 1984). Often, livestock grazing in warm climate regions do not receive adequate mineral supplementation and forages rarely satisfy mineral requirements completely. The historical significance of mineral deficiencies and toxicities for the cattle industry in Florida has been summarized (Cunha et al., 1964; Becker et al., 1965). The purpose of the experiment was to relate soil, forage, and supplement sources of mineral elements to blood serum, bone, liver, hair, feces, and milk macro element composition in Brahman cattle in central Florida. The following chapter evaluates trace element status

Experimental Procedure

The experiment was conducted at the University of Florida Pine Acres Purebred Beef Research Farm located in central Florida. In general, the soils (Entisol) are coarse-textured, acid (pH 6.0) and low in natural fertility. The experimental units were comprised of 36 registered Brahman cows (four to ten years old) in early pregnancy. Initially, the cows had access to Bermuda-Bahiagrass pastures, fresh water from deep wells, and mineral boxes containing a trace mineralized salt block and a mixture of 90% dicalcium phosphate and 10% common white salt. In fall and winter months starting in October, all cows received bermudagrass hay ad libitum. All animals were

negative to brucellosis blood tests and tuberculosis skin test. Cattle were pasture mated to comparable fertile outcross registered Brahman bulls during a 72-day breeding season of March 20 to June 1.

During the 22 month experiment, cows were confined to four fenced pastures (three bahiagrass and one bermudagrass) and grazed rotationally to minimize the effect of pasture on treatments. Fertilization of pastures consisted of 341 kg of 15% (N), 5% (P_2O_5), and 10% (K_2O) per hectare. Cattle were allotted randomly to three lots of 12 cows each. Each lot was offered from November, 1980, to March, 1982, coastal bermudagrass hay ad libitum and one of the three supplements. The three treatments were as follows: 1) control - receiving four pounds of shelled corn-urea concentrate (97% corn meal and 2.57% urea), free choice white salt block (NaCl only) and a complete commercial mineral mixture (20% Ca, 6% P, 25% NaCl, 1% Fe, .15% Cu, .03% Co, .02% Mn, .5% Mg, .04% Zn and .15% F), 2) control plus .25 ppm dietary added Se (97% corn meal, 2.5% urea and .5% sodium selenite) and intramuscular injection of 5 mg Se + 1500 mg vitamin E, and 3) control concentrate mixture plus fortified mineral mixture (8.2%). Ingredient composition is shown in table 4. The mineral composition of hay was as follows: .28% Ca, .10% Mg, .11% P, 5.69% N, .45 ppm Mn, .01% Na, .8% K and .02% Se. The mineral composition of corn meal was as follows: .03% Ca, .14% Mg, .29% P, .37% K, .03% Na, .12% S, .05 ppm Co, 4 ppm Cu, 30 ppm Fe, 5 ppm Mn, .08 ppm Se and 14 ppm Zn. The experiment was divided into six collection periods for soil, forage, and animal tissues. The collection dates, May, 1980, October, 1980, June, 1981, and October, 1981 (1, 2, 4 and 5) were within the wet (June-October) and February,

1981, and March, 1982 (3 and 6) were within the dry (November-May) season. Liver, hair, and serum samples were collected from the 36 cows at the beginning of each of the 6 periods, while bone, feces, and milk samples were taken four times (dates 3, 4, 5 and 6). Calf serum was collected on date 2, 4 and 5 at which time the average ages were 8, 4, and 6 months, respectively. Composite duplicate forage and soil samples were collected six times from the four pastures where cattle were grazing. At the third and sixth collection dates (January, 1981, and March, 1982, the pasture was frosted, mature, about 3 cm in height and composed very little of the diet. Procedures for collection and mineral analysis of liver biopsy, plasma, and forage samples have been described (Fick et al., 1979). Hair samples were clipped from the sides of the animals. Feces samples were collected directly from the rectum and were frozen until analyzed. Soil samples were collected with a stainless steel tube at a depth of 10-20 cm.

Chemical Analysis

Soils were analyzed according to procedure used by University of Florida Soil Testing Analytical Research Laboratory (Nitchel and Rhue, 1979). The mineral analyses as determined by atomic absorption (Perkin-Elmer, 1973) for soil were Ca, Mg, Na, K, P and Al. The ph was determined using a 1:2 soil to water ratio in a standard glass electrode and calomel reference electrode. Forage samples were analyzed (Fick et al., 1975) for the same minerals in the soil, excluding Al. Forage crude protein determination has been described by Technicon Industrial System (1978). Fecal samples were analyzed for Ca and P using methods described by Fick et al (1979). Blood

TABLE 4. INGREDIENT AND ELEMENT COMPOSITION OF FORTIFIED MINERAL SUPPLEMENT, TREATMENT 3.

	% Element or compound in mixture	Requirement	Amount	Correction Factor	Total amount in mix	% of total mixture
BioFos (IMC)[a,b]			66.6 g	0	66.6 g	27.453
a) Ca	18.0	0.28%				
b) P	21.0	0.26%				
Potassium Chloride	60.0	0.60%	31.2 g	0	31.2 g	12.861
Gyma-Mate (IMC)			80.0 g	0	80.0 g	32.976
a) K	18.0	0.90%				
b) S	22.0	0.10%				
c) Mg	11.0	0.18%				
NaCl	100.0	0.10%	50 g	0	50 g	20.610
Selenium Premix	.02	0.10 ppm	2.5 mg	5000	12.5 g	5.153
Cobalt Carbonate	46.0	.1 ppm	1 mg	2.17	2.17 mg	.00089
Cupric Sulfate	25.0	10 ppm	100 mg	4	400 mg	.1649
Manganous Oxide	60.0	25 ppm	125 mg	1.67	208.8 mg	.0861
Zinc Oxide	72.0	50 ppm	500 mg	1.39	695 mg	.2865
Ferrous Carbonate	42.0	30 ppm	150 mg	2.38	357 mg	.1472

New Trace Mineral Premix[c]			635.1 mg	0	635.1 mg	.2618
a) Nickel Sulfate (22.3% Ni)	14.06	2 ppm				
b) Stanous Chloride (52.6% Su)	5.968	2 ppm				
c) Chromium Chloride (19.5% Cr)	0.805	.1 ppm				
d) Ammonium Vanidate (43.5% V)	0.361	.1 ppm				
e) Potassium Iodate (59.3% I)	0.265	.1 ppm				
f) Calcium Carbonate	78.53					
TOTAL					242.6 g	100.00%

[a]Based on 500 kg cattle consuming approximately 10 kg of dry matter.

[b]To provide the following percentage of the requirements: Ca (43.6), P (50.0), K (50.0), S (175.0), Mg (46.9), NaCl (500), Se (250), I (100), Co (100), Cu (100), Mn (50), Zn (100), Fe (50), Ni (100), Sn (100), Cr (100), V (100).

[c]Requirements for new trace minerals estimated with the following forms used: $NiSo_4 \cdot 6H_2O$, $SnCl_2 \cdot 2H_2O$, $CrCl_3 \cdot 6H_2O$, $NH_4 VO_3$

serum samples were deproteinized with 10% trichloroacetic acid (TCA) and then analyzed for mineral content according to methods described by Fick et al. (1979).

Calcium and Mg were analyzed by atomic absorption spectrophotometry (Perkin-Elmer 5000) according to procedures recommended by manufacturers (Anonymous, 1973). Feces, bone, serum, milk, and hair P was determined by the colorimetric technique described by Harris and Popat (1954). Hemoglobin (Hb) was determined by the modification of the colorimetric method of Martinek (1970) and packed cell volume (PCV) by the microhematocrit method. Bone biopsy was collected as described by Little (1972) and analyzed for ash, Ca, P and Mg. Specific gravity was determined for bone samples according to the procedure of Little (1972) as modified by Mtimuni (1982). Bone samples were dried and ether extracted following procedures outlined by Fick et al. (1979). Hair was analyzed for Mg, Na, K and P. Milk and colostrum samples were analyzed for Ca, Mg, P and K by atomic absorption spectrophotometry.

Data were statistically analyzed according to split-plot design (Steel and Torrie, 1960). Data were analyzed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS)(Barr et al., 1976) by analysis of variance to test for significance between treatments, locations, collection periods and their interactions.

Results and Discussion

Forage and Soil Analysis

Mean analysis of soils and forages by period are presented in tables 5 and 6, with analysis of location in appendix tables 28 and 29, respectively. Analysis of variance-mean squares for soil and

TABLE 5 SOIL pH, O.M AND MACRO MINERAL CONCENTRATIONS AS AFFECTED BY SAMPLING PERIODS (DRY BASIS)

Parameter*	Critical† level	Sampling Periods*‡ P1 (4/86) Mean	% Def	P2 (10/86) Mean	% Def	P3 (7/87) Mean	% Def	P4 (4/87) Mean	% Def	P5 (10/87) Mean	% Def	P6 (3/88) Mean	% Def	Overall Mean Mean	% Def	Standard error or range
pH		4 11		4 30		4 63		5 72		5 52		5 68		5 72		
Ca ppm	71	478[1]	0	449[dr]	0	316[a]	0	346[bc]	0	401[d]	0	1.93[1]	0	433	0	80 5-29 1
Mg ppm	4 1	75 0[a]	0	86 8[a]	0	47 8[b]	0	55 0[bc]	0	72 8[cd]	0	65 0[a]	0	72 1	0	4 14 4 4
Na ppm		4 59[a]		5 10[a]		5 30[b]		6 05[a]		8.12[b]		4 15[c]		5 42		224 367
K ppm	59	73 1[c]	75	46 5[a]	100	47 3[b]	50	44 5[b]	25	71 9[c]	75	31 0[cd]	0	55 0	47	15 2-21 4
P ppm	10	79 0[a]	0	76 8[dr]	0	44 8[cd]	0	47 4[dr]	0	44 4[d]	0	32 5[d]	0	78 1	0	2 31 3 24
Al ppm		204[a]		228[a]		221[a]		225[a]		263[b]		244[abc]		227		4 51 4 21
O.M. %		1.68[a]		1 55[a]		1 45[a]		1 44[c]		1 42[cd]		1 73[a]		1 59		025 035

*15 spaces are raised as the following number of samples 0 for period 1 and 4 for periods 2 4

†Critical levels are according to Bruland, 1978 (Ca and Mg) Bahia 1978 (K) and Sanchez 1976 (P)

‡Soil was collected four times during wet (June October) seasons and twice during the dry (November-May) season Periods 4 and 6 fall within the dry season while the rest of the periods are within the wet seasons

Means in the same row with different superscripts differ (P < 05)

TABLE 6. EFFECT OF SAMPLING PERIODS ON MACRO MINERAL COMPOSITION OF FORAGES (DRY BASIS).

Parameter[a]	Critical[5] level	Sampling Periods[c] P 1 (5/80) Mean	% Def	P 2 (10/80) Mean	% Def	P 3 (2/81) Mean	% Def	P 4 (5/81) Mean	% Def	P 5 (10/81) Mean	% Def	P 6 (3/82) Mean	% Def	Overall Mean Mean	% Def	Standard error range
Ca %	30	302[d]	81	415[e]	0	388[e1]	0	370[f3]	0	435[h3]	0	313[d]	75	364	15	.010 .081
Mg, %	20	229[d]	31	218[d]	25	168[de]	60	149[i]	75	230[d]	25	190[d]	25	155	38	678 1 36
Na %	.06	082[i]	75	045[i]	25	012[j]	100	.021[j]	100	.045[ik]	75	033[i]	100	038	85	015 .020
K., %	66	1 691[5]	0	548[e5]	75	113[i]	100	1 453[h5]	0	551[5]	37	1 115[h]	15	920	35	083.. 157
2.. %	25	233[5]	53	269[de]	25	191[i5]	100	120[5]	100	225[5]	0	260[d]	65	239	55	013 .087
Crude protein	7	6 12	100	6 49	100	5 98	100	5 58	100	5 01	100	6 00	100	6 16	100	061 341

[a]15 means are 5mand on the following number of samples 15..9..0 8..8...and 4 periods 1..2..3..1...5...and 5.. respectlvnly...

[b]McDowell and Conr#5....1577

[c]Forage samples were collected four times during wet (June-October) seasons and twice during the dry (November May) season Periods 1 and 5 (all) within the Dry season; while the rest of the periods are within the wet season

5 m 1 5 [h]Means in 1nd same row with 5 different superscripts 5 ifer (2 < 001)

1 1 [i]Means in the same row wit5 different superscripts 5 ifer (2 < 05)

forage mineral concentrations are presented in appendix tables 40 and 41, respectively. Appendix table 42 presents soil and forage mineral concentrations comparing wet vs dry seasons. Forage seasonal differences ($P < .05$) were found for Ca, Mg, K and P, and ($P < .01$) for Na, with concentrations higher during the wet season. Forage nutrient differences among locations were found for Mg and K, with concentrations highest ($P < .01$) for bahiagrass pastures. The only season x location interaction ($P < .05$) was for Ca. Differences among locations ($P < .01$) were found for all measured soil responses (Ca, Mg, P, Al and O.M.), with exception of pH, Na and K.

Mean forage Ca levels during both wet and dry seasons ranged from .30 to .42% and .31 to .39%, respectively, both adequate compared to the NRC (1976) requirement of .30% for growing heifers and mature cows. Of all samples analyzed, 12% and 37% were deficient in Ca during the wet and the dry seasons, respectively. Mean soil extractable Ca varied from 336 to 529 ppm among locations and 316 to 483 ppm between seasons, with higher values ($P < .05$) during the wet season. All soil samples analyzed were above the critical level (< 71 ppm).

Extractable soil P showed significant location (species) and season differences, with higher values ($P < .01$) in bermudagrass and ($P < .05$) in the wet season. All mean soil P values by location and period were above the normal range of 11 to 30 ppm indicated by Babra (1976). Forage P levels varied from .20 to .23% during the dry and wet seasons, respectively, and from .22 to .25 among locations. Mean forage P concentrations in Florida pastures have been reported to be low, especially during the dry season with Becker et al. (1965) reporting a decrease in forage P levels from .23% in April to .11% in

July. Forage P was higher ($P < .05$) during the wet season and, of all forages analyzed, 47 and 82% were deficient (< .25%) during the wet and dry seasons, respectively.

Mean extractable soil Mg did not vary ($P > .05$) between season, but there was (species) location difference with higher concentrations ($P < .01$) in bahiagrass than in bermudagrass pastures. Florida soils with adequate concentrations of extractable Mg have been reported to contain 4.2 to 21.1 ppm Mg (Breland, 1978). Magnesium was not deficient in all soil samples analyzed based on a critical level of 5.1 ppm (Breland, 1978). Mean forage Mg levels were adequate (.20%) in the wet season, but low (.17%) in the dry season. In all locations during the dry season, mean forage Mg content was less than the recommended requirement of .18% (NRC, 1976).

According to Bahia (1978), less than 80 ppm and more than 120 ppm of soil available K are considered as low and high concentrations of this element. Mean soil K for locations I, II, III and IV were reported as 59, 58, 88, and 72 ppm, respectively. On the basis of the cited critical level of 60 ppm, 43, 63, 43, and 43% of the soil samples were low in extractable K in locations I, II, III and IV, respectively (appendix table 26). Gammon (1957) previously indicated that K leaching in some Florida soils was so high that annual application of K was recommended for good crop production. The Ultisols have a greater capacity for K retention than the Entisols of Florida (Selim et al., 1976). Borderline to deficient concentrations of soil K was found in the wet and dry seasons as 68 and 25% of the total soils, respectively. Borderline to deficient concentrations of forage K (< .60%) were found in the wet and dry seasons as 25 and 58%

of total samples, respectively. Forage K was higher ($P < .001$) in the wet season than dry season. Similar K forage seasonal variations have been reported previously (Gamble et al., 1969; Kiatoko et al., 1982).

Mean extractable soil Na did not show significant difference ($P > .05$) between locations, however, its level was higher ($P < .05$) during the wet season. Mean soil extractable Na varied from 6.04 to 8.12 ppm in the wet season and from 4.15 to 8.00 ppm during the dry season. Forage Na was higher ($P < .05$) during the wet season (.06 vs .02% for the dry season). Among locations, Na varied from .02 to .08% in the wet season and from .01 to .03% in the dry season. Forage Na deficiencies (< .06% for mature cows) were much higher during the dry (November-May) vs wet season (June-October). Individual evaluation of the forage samples indicated 69 and 100% of all samples analyzed were deficient (< .06%) in Na during the wet and dry seasons, respectively. Kiatoko et al. (1982) reported similar low forage Na concentrations from four regions in Florida. Becker et al. (1965) observed that certain regions of Florida are characterized by high concentrations of salt in both water and forages which caused cattle to avoid mineral mixtures based on high salt contents.

Mean forage protein content was 6.3% during the wet season and 6.0% for the dry season. There was no difference ($P > .05$) among locations and seasons, nor were there any period x location interactions. During both wet and dry seasons, all forage protein concentrations were below the critical level of 7% (McDowell and Conrad, 1977). Kiatoko et al. (1982) indicated that of all forages analyzed, only 16% contain less than the critical level of protein (7%) during the wet season and 60% during the dry season.

Mean exchangeable Al varied from 190 to 309 ppm among locations with no significant differences ($P > .05$). Although Al was expressed as a percent of sum of exchangeable bases (Ca, Mg, Na, K), but not as percent of cation exchange capacity (CEC), Al saturation did not approach the critical level of 60% above which Al neutralization results in improved plant growth (Mendez and Kamprath, 1978). Average exchangeable Al levels of .19 meq/100 g have been reported in the Astatula soil series (Entisol) of Florida (Khonvilai and Blue, 1977).

Calcium, Phosphorus, Magnesium, and Potassium Tissue Analyses

Appendix table 43 presents tissue mineral concentrations of the wet vs the dry season. Mean blood serum mineral concentrations are presented by treatment and period in tables 7 and 8. Appendix tables 34 and 36 present analysis of variance-mean square for calf and cow serum mineral contents, respectively. Mean bone, feces, hair, and milk mineral concentrations are presented by treatment in tables 9 and 10 and appendix tables 30 and 31, and by period in tables 11-14, respectively. Appendix tables 33, 35, 38, and 39 show analysis of variance-mean square for bone, feces, hair and milk, respectively.

In general, unlike mineral concentrations in forages, mineral concentrations in animal tissues were lower ($P < .05$) during the rainy vs dry season. Consequently, percent borderline to deficient samples were higher in the rainy season than in the dry season. Others (McDowell, 1976, Lebdosoekoho, 1977, McDowell and Conrad, 1977, Mendez, 1977, Sousa, 1978) have observed that whereas mineral deficiencies in forages are prevalent in dry season, mineral deficiencies in animals are prevalent in the rainy season. During this time, forages are supplying plentiful energy and protein which

TABLE 7. COW AND CALF SERUM MACRO MINERAL CONCENTRATIONS AS AFFECTED BY TREATMENT.

Parameter*	Critical+ level	Animal class	Mineral Supplementation T_1 Mean	T_1 % Def	T_2 Mean	T_2 % Def	T_3 Mean	T_3 % Def	Standard error range
Ca, mg/100 ml	8	cow	8.3	22	9.0	21	8.6	23	.20-.22
		calf	8.0	51	8.2	53	7.9	58	.16-.18
P, mg/100 ml	4.5	cow	5.0	36	5.2	28	5.0	35	.009-.13
		calf	8.5		8.3		8.7		.16-.19
Mg, mg/100 ml	2	cow	2.3	12	2.4^{ab}	16	2.3	14	.015-.03
		calf	2.1^{a}	26	2.2^{ab}	28	2.3^{b}	32	.04-.05
Hb, %		cow	13.1		13.0		13.7		.035-.18
		calf							
PCV		cow	39.7^{a}		40.0^{a}		37.9^{b}		.60-.85
		calf							

*LS means are based on the following number of samples: cows, 66, 69, and 66; calves, 35, 34, and 31 for treatments 1, 2, and 3, respectively.

+McDowell, 1970; McDowell and Conrad, 1977.

T_1, T_2, and T_3 stand for control, control plus Selenium, and fortified mineral supplementation, respectively.

^{a,b}Means in the same row with different superscripts differ ($P < .05$)

TABLE 8 COW AND CALF SERUM MACRO MINERAL CONCENTRATIONS AS AFFECTED BY PERIODS.

Parameter[1]	Critical[2] level	Animal class	Sampling Periods[3] P 1 (5/81) Mean	P 1 (5/81) % Def	P (10/80) Mean	P (10/80) % Def	P 1 (2/81) Mean	P 1 (2/81) % Def	P (6/81) Mean	P (6/81) % Def	P (10/81) Mean	P (10/81) % Def	P (3/82) Mean	P (3/82) % Def	Overall Mean Mean	Overall Mean % Def	Significant error range
Ca mg/100 ml	H	cow	11 3[a]	6	H 5[b]	3	H 7[B]	7	2 3[c]	81	H 3[ab]	17	7 3[c]	28	H 7	P3	20- 3P
		calf			H 0	20			7.8	72	H P	HF			H H	5P	IH IH
P mg/100 ml	< H	cow	5.0[b]	40	H 2[a]	6	5 1[b]	17	H 1[c]	71	H 3[b]	17	H H[c]	50	H 0	34	17 .20
		calf			H.2[a]				H.H[c]		H 2[a]				H H		IH .20
Mg mg/100 ml	P	cow	P 4[a]	3	2.2[B]	3	1 9[c]	70	2 6[B]	2	2 3[a]	6	2 3[b]	5	2 3	1H	03 06
		calf			P P	11			1 H	HH	2 H	H			2 P	27	04 HH
Hb H		cow	12 H[b]		H 8[b]		11 H[c]		12 6[B]		1H 3[a]		1H 2[a]		13 6		80 .23
		calf			11.4[c]				12 2[a]		15 2[a]				13 6		75 P2
PCV %		cow	13 4[B]		1P P[a]		16 9[b]		36 H[c]		35 4[c]		37 6[c]		3H P		11 03
		calf			43 H[B]				40 2[c]		02 1[B]				H3 H		20- HH

1H means are based on the following number of samples cows 26 36 31 33 26 and 35 for periods 1-6, respectively; calves 35 36 and 34 for periods P, H and H respectively.

[2]McDowell 1976 McDowell and Conrad 1977

[3]Serum was collected from cows for times during the wet (June-October) season and twice dur ing the dry (November-May) season and three times from calves Periods 2 and H fell within the dry season while the rest of the periods fe within the wet season

H,b,c Means in the same row with different superscripts differ (P < 001)

H [a]Means in the same row with different superscript differ (P = 05)

TABLE 9. BONE MINERAL CONCENTRATIONS AS AFFECTED BY TREATMENT

Parameter*	Critical[a] level	Mineral Supplementation T_1 Mean	T_1 % Def	T_2 Mean	T_2 % Def	T_3 Mean	T_3 % Def	Overall mean Mean	Overall mean % Def	Standard error range
Bone (DM Fat Free)										
Ca, %	24.5	23.8[b]	49	24.3[bc]	46	24.7[c]	45	24.2	47	.18-.20
P, %	11.5	10.3	93	10.5	86	10.5	78	10.4	86	.10-.12
Mg, %		.40		.40		.40		.40		.0001
Ash, %	66.5	63.3	95	64.3	96	64.1	98	63.9	96	.21-.23
Ca, % Ash	37.5	37.6[d]	31	37.7[d]	31	38.7[e]	32	38.0	31	.30-.34
P, % Ash	17.5	16.3	90	16.2	88	16.4	80	16.2	86	.16-.18
Mg, % Ash		.63		.61		.66		.62		.015-.02
Specific Gravity										
gm/cc	1.68	1.75	18	1.68	31	1.71	46	1.69	32	.002-.025
Ca, mg/cc		418		423		435		426		6.0-6.7
P, mg/cc		181		182		184		183		2.7-3.0
Mg, mg/cc		7.00		6.80		7.30		7.0		.19-.21
Ca P ratio		2.32		2.34		2.37		2.34		.01-.028

*LS means are based on the following number of samples: 43, 46, and 42 for treatment 1, 2, and 3, respectively.

[a]Critical levels are according to Little, 1972 (Ca, P, Ash and Specific gravity) and McDowell et al., 1983 (Ca and P, % Ash).

T_1, T_2, and T_3 stand for control, control plus Selenium and fortified mineral supplement, respectively.

[b,c]Means in the same row with different superscripts differ ($P < .01$).

[d,e]Means in the same row with different superscripts differ ($P < .05$).

TABLE 10. FECAL MINERAL CONCENTRATIONS AS AFFECTED BY TREATMENT

Parameter[a]	Treatment[b]			SER[c]
	T_1	T_2	T_3	
Ca, %	.933	1.07	1.024	.047-.056
P, %	.630	.575	.675	.023-.027

[a]LS means are based on the following number of samples 44, 45 and 41 for treatments 1, 2 and 3, respectively.

[b]Treatments 1, 2 and 3 (T_1, T_2 and T_3) are control, control plus Se and fortified mineral supplements, respectively.

[c]Standard error range.

Fecal Ca and P showed no difference ($P < .05$) among treatments, but they are higher in treatments 2 and 3.

increases animal mineral requirements for the rapid growth rate in the rainy season. Significant period x treatment interactions ($P < .05$) were found only for the feces Ca and colostrum P. Seasonal nutrient differences were found with feces Ca, P and hair P to be higher ($P < .05$) in the dry vs wet season, while hair Na, milk Ca, Mg and serum Mg were higher ($P < .05$) during the wet season.

Mean serum Ca concentration did not vary ($P > .05$) between seasons. Mean serum Ca was 9.0 and 8.4 mg/100 ml in the wet and dry season, respectively. These values were in close agreement with those reported by Kiatoko et al. (1982). Both mean serum Ca in the wet and dry seasons were above the critical concentration of 8 mg/100 ml suggested by Cunha et al. (1964). Mean mineral concentrations of bone, milk, feces, hair and serum were not affected by mineral supplementation with exception of bone Ca and ash (dry, fat-free), Ca (% ash) and calf serum Mg. Mean bone Ca and ash (dry, fat-free) and Ca (% ash) were higher ($P < .05$) in animals receiving fortified minerals (treatment III). Bone Ca did not show differences ($P > .05$) between seasons. Individual evaluation of samples indicated 45 and 53% of all samples analyzed were low in Ca according to critical level of 24-5 for normal animals in the wet and dry seasons, respectively (Little, 1972). Means of rib bone Ca-P ratios did not agree with reported values in the literature. The constant ratio may be due to analytical error. Calcium deficiencies, though reported rare in grazing animals (McDowell, 1976), have been known to occur. Peducasse (1982) reported the incidence of Ca deficiency in Bolivia to be 100% as indicated by bone Ca and 43% as indicated by blood serum Ca. Mean Ca concentrations in feces, bone and milk varied from 8.9, 24.4, and

.135% during the wet season to 1.12, 24 3, and .124% during the dry season, respectively.

Mean serum P concentration was 5.2 and 4.8 mg/100 ml in the wet and dry seasons, respectively; both above the critical level of 4 5 mg/100 ml (Underwood, 1966) However, of all animals studied, 35% had low serum P during the wet season, while 34% had low serum P during the dry season. Serum P is affected by many factors (Gartner et al., 1965, Fick et al., 1979) with some researchers not recommending it as a criterion for P assessment in cattle (Committee on Animal Nutrition, 1973).

Mean fecal P showed seasonal variations, with higher levels ($P < .05$) during the dry season than the wet season, .80 vs .52%. Any changes in the dietary P levels will be reflected in the output of the fecal P. The low fecal P in the wet season may be due to the fact that, during this period, protein and energy are plentiful which increase animal requirements for individual minerals to meet the rapid growth rate. These findings were in disagreement with those reported by Cahen (1974) and Winks et al. (1977). They observed that, as P content of forages decreased during the dry season, fecal P concentration likewise decreased. Differences ($P < .01$) were found in hair P concentrations, which were higher in the dry season than in the wet season (248 vs 172 ppm). These results agree with the report from Florida in which cattle hair P concentrations were higher in the dry season than the wet season (215 vs 104 ppm)(Kiatoko et al., 1982). However, the data are in disagreement with the report from Australia indicating no season effect on hair P concentrations (Cahen, 1973). Kiatoka et al. (1982) suggested that accumulation of P in hair during

TABLE 11. BONE MINERAL CONCENTRATIONS AS AFFECTED BY SAMPLING PERIODS.

Parameter*	Critical[a] level	Sampling periods: P 3 (2/81) Mean	% Def	P 4 (6/81) Mean	% Def	P 5 (10/81) Mean	% Def	P 6 (3/82) Mean	% Def	Overall Mean	% Def	S.E. range[†]
Bone (D.M. Fat Free)												
Ca, %	24.5	23.0[b]	97	25.9[c]	3	22.8[b]	86	25.5[c]	3	24.3	49	.21-.23
P, %	11.5	10.7[d]	73	10.4[d]	91	10.2[e]	94	10.6[d]	88	10.4	87	.11-.14
Mg, %		.41[b]		.42[b]		.41[b]		.35[c]		.40		.01-.02
Ash, %	66.5	63.3[b]	100	63.8[b]	88	63.5[b]	89	65.1[c]	82	63.9	89	.23-.27
Ca, % Ash	37.6	36.3[b]	79	40.6[c]	0	35.9[b]	85	39.4[c]	3	38.0	42	.34-.38
P, % Ash	17.6	16.8[d]	69	16.2[e]	94	16.0[e]	91	16.2[e]	88	16.2	86	.18-.20
Mg, % Ash		65[d]		66[d]		65[d]		57[e]		62		.02
Specific Gravity												
gm/cc	1.68	1.70[b]	40	1.72[b]	36	1.69[b]	46	1.88[c]	3	1.75	31	.02
Ca, mg/cc		390[b]		446[c]		384[b]		481[c]		426		6.8-7.6
P, mg/cc		182[d]		178[d]		712[d]		198[e]		182		3.0-3.4
Mg, mg/cc		6.88		7.29		6.93		6.84		7.04		.22-.26
Ca:P ratio		2.16[b]		2.52[c]		2.24[b]		2.44[c]		2.35		.03-.04

*LS means are based on the following number of samples: 23, 33, 34, and 32 for periods 3, 4, 5, and 6, respectively.

†Standard error range.

[a]Critical levels are according to Little, 1972 {Ca, P, Ash and specific gravity} and McDowell et al., 1983 (Ca and P, % Ash).

P_3 and P_6 represent the dry season while P_4 and P_5 represent the wet season.

[b,c]Means in the same row with different superscripts differ ($P < .001$)

[d,e]Means in the same row with different superscripts differ ($P < .01$)

TABLE 12 FECAL MINERAL CONCENTRATIONS AS AFFECTED BY PERIODS

Parameter[a]	Period[b] P_3 (2/81)	P_4 (6/81)	P_5 (10/81)	P_6 (3/82)	S.E.R[c]
Ca, %	.767[f]	1.224[e]	.563[g]	1.485[d]	.55 - .61
P, %	.687[e]	.697[e]	.340[f]	.916[d]	.027-.029

[a]LS means are based on the following number of samples: 34, 32, 33 and 31 for periods 3, 4, 5 and 6, respectively.

[b]Periods 3 and 6 represent the dry season (November-May) while periods 4 and 5 represent the wet season (June-October).

[c]Standard error range

[d,e,f,g]Means in the same row with different superscripts differ ($P < .001$).

TABLE 13. EFFECT OF PERIOD ON HAIR MACRO ELEMENT CONCENTRATIONS

Parameter*	Sampling periods++						S E R +
	P_1 (5/80)	P_2 (10/80)	P_3 (2/81)	P_4 (6/81)	P_5 (10/81)	P_6 (3/82)	
Hair (ppm)							
Mg	216^{a}	174^{a}	81^{b}	270^{c}	127^{ad}	283^{ce}	16.3-21.8
Na	61^{a}	90^{b}	56^{a}	87^{bc}	85^{bd}	48^{a}	7.2-8.4
K	86^{a}	113^{b}	44^{c}	123^{bd}	86^{a}	172^{e}	9.0-11.1
P	175^{a}	153^{a}	235^{b}	192^{ac}	166^{a}	261^{bd}	11.1-13.1

*LS means are based on the following number of samples: 36, 36, 31, 32, 36 and 28 for periods, 1, 2, 3, 4, 5, and 6, respectively

+Standard error range.

++Hair samples were collected four times during the wet (June-October) season and twice during the dry (November-May) season. Periods 3 and 6 fall within the dry season, while the rest of the periods are within the wet season.

a,b,c,d,eMeans in the same row with different superscripts differ ($P < .001$)

TABLE 14. EFFECT OF PERIODS ON MILK AND COLOSTRUM MACRO MINERAL CONCENTRATIONS

Sampling period*	Ca %	P %	Mg ug/ml	K %
Milk				
P_1 (5/80)	.148[a]	.105[a]	80[a]	.135[a]
P_3 (2/81)	.123[b]	.092[a]	60[b]	.091[b]
P_4 (6/81)	.129[b]	.100[a]	63[b]	.100[b]
P_6 (3/82)	.125[b]	.079[b]	64[b]	.091[b]
S.E. Range+	.002-.007	.003	2.1-3.0	.070
Colostrum				
P_3 (2/81)	.137	.103	212	.093
P_6 (3/82)	.147	.161	230	.092
S.E. Range+	.004	.0032	7-12	.0038

*LS means are based on the following number of samples: milk, 34, 25, 25, and 28 for periods 1, 3, 4, and 6, colostrum, 36 and 35 for periods 3 and 6, respectively.

+Standard error range.

[a,b]Means in the same column with different superscripts differ ($P < .01$).

the dry season had a physiological means of mineral storage during a period when the P requirement is low. Phosphorus deficiency in grazing cattle has been a serious problem in Florida (Becker et al., 1933a, 1965). More recently, Shirley et al. (1968) and Kiatoko et al. (1982) emphasized the seriousness of P deficiency in Florida.

Magnesium concentrations were higher ($P < .05$) during the wet season than dry season in serum (2.5 vs 2.1 mg/100 ml), hair (186 vs 182 ppm) and milk (72 vs 62 ppm). Mean serum Mg concentrations for both seasons were adequate compared to the critical level of 1.8 mg/100 ml (Underwood, 1966). Only a small percentage of animals had serum Mg concentrations below the critical level (< 1.8 mg/100 ml), 4 and 38% during the wet and dry seasons, respectively.

Bone ash

Bone ash did not show season ($P > .05$) variations. The magnitude of bone ash deficiency, 45 and 91% in the wet and dry seasons, respectively, partially agreed with magnitude of deficiencies in blood Ca (23%) and bone Ca (48%)(average for the dry and wet season). Bone Mg did not show seasonal variations ($P > .05$), but was higher during the wet than dry season.

Specific gravity

Specific gravity did not show variation ($P > .05$) between seasons or treatments; however, all treatments were above critical level of 1.68 gm/cc (Little, 1972) based on the magnitude of percent deficiency in bone Ca, P and ash and, accepting these parameters as direct measurements of bone changes and the practical indicators of bone mineralization available, for assessment of Ca and P nutrition of cattle in this study.

Relationship of Minerals in Animal Tissues

Correlation coefficients in animal tissues are presented in appendix table 53. Correlation coefficients between soil, forage and animal tissues were not computed because cattle in this experiment grazed communally, such correlation coefficients have been found to be small or nonexistent (Conrad et al., 1980). Correlation coefficients which do not explain about 25% of the total variation in mineral content of soil, forage or animal tissues cast doubt as to their practical significance or to their reproducibility in subsequent investigations. Consequently, this criterion has been used to evaluate correlation coefficients.

Blood correlations

Considering values of correlation coefficients greater or equal to ± .5 and at significant level of P = .05, only Ca positively correlated with Mg, at the probability level of .01 and the r value was .52. Lehdosoekojo (1977) did not find a correlation (P > .05) greater than or equal to ± .5 in blood.

Liver correlations

There were no correlation coefficients greater than or equal to ± .5 at the probability level of .05.

Bone correlations

Mineral correlations between animal tissues did not correlate with each other with a correlation coefficient of greater than or equal to ± .5 at the probability level of .05. This clearly demonstrates the problem of finding significant correlation coefficients between soil, forage and animal tissues as has been observed by others (Conrad et al., 1980). None of the correlation

coefficients between animal tissues met the criterion ($r \pm .6$, $P = .05$), confirming observations by Paducasse et al (1993) and Mtimuni (1982).

Soil Correlations

Correlation coefficients in soil are presented in appendix table 52. Significant correlation coefficients with pH greater than or equal to ±.6 at probability level of .01 were found with extractable soil Ca and Mg at probability level of .01 and the r values were .66 and .69, while it was negatively correlated with Al at probability level of .01 and r value was -.68. Extractable soil Mg correlated significantly with extractable soil Ca at probability level of .001 and the r value was .92. Aluminum saturation correlated significantly with extractable P at probability level of .001 and the r value was .76. Correlation coefficients between soil parameters in this study agreed with those reported by Mtimuni (1982) for Malawi, but were generally smaller than those reported by Sousa (1979) in Brazilian soils.

Forage Correlations

There were no correlation coefficients greater than or equal to ±.6 at the probability level of .05. It is doubtful whether these correlation coefficients could be reproduced in future investigations, based on mineral interactions and many other factors affecting mineral availability from soil to plants and from plants to animals. Correlation coefficients between animal tissues and forage parameters are presented in appendix table 54. Fecal P correlated positively with forage Na at probability level of .01 and the r value was .53. Hair P correlated negatively with forage P, Mg and K at the probability level of .01 and

the r values are -.51, -.52 and -.58, respectively. Macro element correlation with trace elements will be discussed in the next chapter (Chapter V).

Summary

A 22-month experiment was conducted to determine the macro mineral status of purebred Brahman beef cattle grazing bermudagrass-bahiagrass pastures grown on sandy and well drained soils in central Florida. Liver, bone, blood, hair, milk and feces from 36 cows in early pregnancy, plus soil and forage samples were collected 4 times during the wet season and twice during the dry season.

Soil analysis for the 4 locations showed adequate concentrations of Ca, Mg and P during both the wet and dry seasons. However, 69 and 25% of all soil samples analyzed for K in the wet and dry seasons, respectively, were below the critical level of 60 ppm. Extractable soil Ca, K and P showed seasonal variations with higher ($P < .05$) levels during the wet vs dry seasons. Forage seasonal differences ($P < .05$) were higher in the wet vs dry season for P, Ca, K and Na. Forage P was higher ($P < .05$) during the wet season, and of all forage samples analyzed, 47 and 63% were deficient (< 25%) during the wet and dry seasons, respectively. Eleven and 36 of the forages provided Ca values less than the requirement of .3% for grazing cattle. Of all forage samples analyzed for Mg, Na and K were below critical levels during the wet and dry seasons (38 and 38, 6% and 100, and 25 and 58%, respectively). Crude protein was deficient (<7%) in the wet and dry seasons. In agreement with P and Ca concentrations in forages, borderline to deficient concentrations of bone, Ca, P (dry, fat-free

basis), ash and specific gravity were found in the wet and dry seasons (45 and 91, 93 and 61, 81 and 91, and 41 and 22%, respectivaly)

Of all samples analyzed, borderline to deficient concentrations of serum Ca (<8) and P (<4.5) were found in the wet and dry seasons (27 and 15, and 32 and 27%, respectively). Mean fecal P showed seasonal variations, with higher ($P < .05$) levels during the dry vs wet seasons. The low fecal P in the wet season may be due to increased requirements of animals. Of the six macro minerals studied, those most likely to be deficient were K, Na, P, Ca and Mg.

CHAPTER V
RELATIVE COMPOSITION OF TRACE ELEMENTS
IN SOIL, DIET AND TISSUES OF BRAHMAN CATTLE

Introduction

For some trace elements (Mn, Fe, Zn, Cu, and Co), there is a negative relationship between soil pH and the quantity of the material available to the plant, while for others (Mo and Se), it is positive (Pfander, 1971; Hartmans, 1970). Soil ingestion can greatly affect mineral intake. This ingestion can be beneficial with elements such as Co or I and, in some circumstances, with Cu, Zn and Se (Underwood, 1979). Cary et al. (1967) indicated that the Entisols of Florida contained more soluble Se than any other soils. Similarly the leaching of Se in Entisols was higher than other soils. The authors concluded that Entisols are predisposed to contain deficient levels because of high solubility and high leaching of Se in these soils.

It was noted that, in warm climate regions, an increase of 20 to more than 100% in calving percentage and 10 to 25% reduction in mortality can result from mineral supplementation (McDowell and Conrad, 1977). Florida trace mineral deficiencies, as evidenced by low forage and(or) animal tissue concentration or decreased performance, have been established for Co, Cu, Fe (Becker et al., 1965) and Se (Shirley et al., 1966). More recently, research from four soil order regions of Florida has shown low Se status of

pastures, soils and animal tissues (McDowell et al., 1982). Inadequate Se status observed in this study plus persistent reports of white muscle disease in the state emphasizes the need for increasing dietary intake of Se. The authors also noted that Se and Zn deficiencies were present in all four regions, while Cu and Co deficiencies were found in certain regions and were related to season of the year. The objectives of the present study were to relate soil, forage and supplement sources of mineral elements to blood, bone, liver, hair, feces, and milk trace element composition in Brahman cattle in central Florida.

Experimental Procedure

The experimental units were comprised of 36 registered purebred Brahman cows (4 to 10 years old) in early pregnancy. Cattle were allotted randomly to 3 treatments of 12 cows per treatment as follows: control, high in Se, and fortified mineral supplement. The soil (Entisol) was sandy and well drained and pastures were exclusively bermudagrass (Cynodon dactylon) and bahiagrass (Paspalum notatum).

Liver biopsy, hair, blood, milk, forage, and soil samples were collected for mineral analysis during both the wet (4 times) and dry (2 times) seasons while bone biopsy and feces samples were collected four times (twice in both the wet and dry seasons). Description of cattle, site of the experiment, and methods for the collection and preparation of samples have been described by Fick et al. (1979) and in the previous chapter (Chapter IV).

Liver biopsy samples (.2 to .6 g) were pre-ashed on a hot plate with concentrated nitric acid and then ashed overnight in a muffle furnace at 550° C. Ash was solubilized by digestion first with 50%

nitric acid, secondly with 10% nitric acid, and finally with distilled water. Solutions were filtered, diluted to appropriate detection level and analyzed by spectrophotometry for Cu, Fe, Mn and Zn (Perkin-Elmer, 1973). Liver Mo and Co were determined with an atomic absorption spectrophotometer equipped with a graphite furnace and D_2 corrector. Blood serum samples were deproteinized with 10% trichloroacetic acid (TCA) and then analyzed for Fe, Cu and Zn by atomic absorption spectrophotometry (Perkin-Elmer Model 5000) according to methods described by Fick et al. (1979). Serum, liver, milk, feces, forage, soil, and hair Se were analyzed by a modification of the fluorometric method (Whetter and Ullrey, 1978). Hair samples were soaked in solution of acetonex for 2d, washed with distilled water, dried in an oven at 60° C for 3 d, and then ashed in a muffle furnace at 550° C. Milk and colostrum samples (20 and 15 ml, respectively) were dried overnight in an oven at 60° C and then ashed overnight in a muffle furnace at 550° C. Solutions of hair, milk and colostrum were prepared in the manner described for liver and analyzed for Fe, Cu, Zn, Mn, Mo and Se. Fecal samples were analyzed for Cu, Se and Zn. Cobalt, Cu, Fe, Mn, Mo, Se and Zn were analyzed in both forages and soils as described previously. Statistical procedures have also been described in Chapter IV.

Results and Discussion

Forage and Soil Analysis

Mean analysis of soil and forage by period are presented in tables 15 and 16 with analysis by location in appendix tables 44 and 45, respectively. Analysis of variance-mean squares for soil and forage mineral concentrations are presented in appendix tables 40 and

TABLE 16 SOIL TRACE MINERAL CONCENTRATIONS AS AFFECTED BY PERIODS OF SAMPLING (DRY BASIS)

Parameter*	Critical† level	Sampling Periods* P_1 (5/80) Mean	% Def	P_2 (10/80) Mean	% Def	P_3 (2/81) Mean	% Def	P_4 (6/81) Mean	% Def	P_5 (12/81) Mean	% Def	P_6 (3/82) Mean	% Def	Overall Mean Mean	% Def	Standard error range
Soil (ppm)																
Cu	00	.806[a]	76	1 112[a]	50	710[b]	00	728[b]	76	.810	00	830[ac]	75	784	64	002 .032
Fe	10	18 2[d]	42 5	22 6[b]	25	28 0[c]	00	18.8[ab]	75	18 2[bc]	75	20 1[dc]	50	19 6	57	35 50
Mn	19	= 36[a]	100	= 60[b]	100	5 85[c]	100	5 25[d]	100	5 ==[dc]	100	= 13[ab]	100	3 00	100	104 140
Zn	2	1 01[a]	75	68[b]	100	72[b]	100	96[a]	75	65[bc]	100	84[a]	100	80	85	061 .04=
Co	1	017	100	02=	100	033	100	020	100	035	100	033	100	026	100	002 .005
Se	6	035[c]	100	042[b]	100	047[ab]	100	040[bc]	100	002[a]	100	045[b]	100	043	100	001 .002

*16 means are based on the following number of samples: 8 for period 1 and = for each of periods 2, 3, 4, 5, and 6, respectively.

†Critical levels are according to Jurowitz and Bantes 1975 (Cu); Comm= nt #1 1980 (Fe and Mn); Sanchez 1976 (Zn); Kubota 1968 (Co) and Cary [Ed] (Se).

‡Soil samples were collected four times during wet (June October) season and twice during dry (November May) season. Periods 5 and 6 fall within the dry season, while the rest are within the wet season.

a,b,c,d Means in the same row with different superscripts differ (P < 1).

TABLE 16. EFFECT OF SAMPLING PERIODS ON TRACE MINERAL COMPOSITION OF FORAGES (DRY BASIS)

Parameter[a]	Critical[b] level	Sampling Periods[++] P_1 (6/80) Mean	% Def	P_2 (7/80) Mean	% Def	P_3 (8/80) Mean	% Def	P_4 (9/80) Mean	% Def	P_5 (10/80) Mean	% Def	P_6 (3/81) Mean	% Def	Overall Mean	% Def	Standard error range
Forage (ppm)																
Cu	10	6.86[c]	38	3.86[d]	100	3.54[e]	100	6.28[bc]	100	3.62[a]	100	6.13[c]	100	5.52	81	951-1.92
Fe	30	24.2[a]	62	54.3[b]	0	76.6[bc]	0	80.2[cd]	0	56.8[bc]	0	80.1[df]	0	63.3	10	2.66-4.86
Mn	6	.22[a]	0	219[b]	0	166[bc]	0	168[c]	0	230[a]	0	190[ad]	0	155	0	813 256
Mo	30	78.6	62	53.0	0	82.0	25	58.0	25	63.3	0	82.0	0	68.3	12	6.84-6.66
Se	1	.035[a]	100	.031[ab]	100	.032[a]	100	.049[b]	100	.032[a]	100	.020[c]	100	.033	100	.002 .005
Zn	30	18.7	100	21.0	75	24.2	75	24.2	75	21.3	00	30.0	50	23.6	81	666 1.94
Co	1	.117	25	.133	13	.120	13	.117	25	.133	13	.160	0	.131	17	.010 .020

[a]LS means are based on the following number of samples: 16, 8, 8, 8, 8, and 6 for periods 1-6, respectively.

[b]McDowell and Conrad, 1977.

[++]Forage samples were collected from times during wet (June-October) season and twice during dry (November-May) season. Periods 3 and 6 fall within the hay season, while the rest are within the wet season.

[a-e]Means in the same row with different superscripts differ (P < .001).

41, respectively. Appendix table 49 presents soil and forage mineral concentrations comparing the wet vs dry seasons. For each soil trace mineral, no differences ($P > .05$) were found between seasons, but differences were found ($P < .01$) between periods of collection excluding Co. Extractable soil Cu, Fe, Mn and Zn varied ($P < .001$) between locations. Seasonal differences ($P < .05$) existed in all forage trace minerals analyzed with the exception of Cu and Co. For each forage trace mineral, differences for Cu, Fe, Mo ($P < .01$) and for Mn, Se and Zn ($P < .001$) were found among locations. Significant period x location interactions were found for soil Cu, Fe, Mn, and Zn and forage Mn, Mo and Se.

Mean soil Co values in the four locations varied from .021 to .031 ppm. Kubota (1968) reported mean extractable soil Co concentrations to range for .11 to 1.40 in healthy pastures. No differences ($P > .05$) in soil Co concentration were found between seasons or among locations. All soil samples analyzed were deficient in Co based on the critical value of < .1 ppm (Kubota, 1968).

Forage Co varied from .117-.133 ppm among the four locations in the wet season and from .120 to .158 ppm in the dry season. On the basis of mean analysis, Co values generally were above the NRC (1976) requirement of .1 ppm. However, evaluation of individual forage concentrations indicated that 19 and 7% of all samples analyzed were low in Co (< .1 ppm) during the wet and dry seasons, respectively. The overall (wet and dry seasons) Co deficiencies were 13% of all forage analyzed as compared to 100% of all soil samples analyzed. Cobalt deficiency was more widespread in the soils and uptake of forage Co appeared to be relatively sufficient from the acidic soils.

This illustrates the general observation that the level of a mineral in the soil does not necessarily indicate its availability to plants growing on that soil (Underwood, 1977. Reid and Howath, 1980).

Mean extractable soil Cu values were .84 and .77 ppm in the wet and dry season, respectively. Of all samples analyzed, 63 and 64% were deficient for the wet and dry season, respectively, in Cu based on the critical level of .6 ppm. Differences ($P < .001$) were found between locations, with higher levels in bermudagrass vs bahiagrass pastures. Horowitz and Oantas (1973) reported that normal soils had between 2.2 and 75 ppm Cu in the surface horizon with values less than .6 ppm considered to be deficient. Mean forage Cu values were 4.4 and 4.9 ppm in the wet and dry season, respectively. Those forage Cu concentrations were not adequate compared to the minimum requirement of 8 ppm (McDowell et al , 1984). Davis (1954) indicated that, in most Florida forages, Cu concentrations on the order of 5 ppm were adequate for cattle nutrition when Mo in forages was less than 1 ppm. Mean forage Mo concentrations were .20 and .18 ppm in the wet and dry season, respectively. McDowell et al. (1982) reported higher forage Mo values for Florida forages in the range of .36 to .65 ppm during the wet and dry season. Forage Mo differed ($P < .01$) between locations and periods. Florida pastures with 2 to 3 ppm Mo should contain at least 10 ppm Cu, while forages with more Mo should contain 50 ppm Cu or more (Davis, 1954).

Extractable soil Fe did not vary ($P > .05$) between the wet and dry sessons, but differed ($P < .001$) among locations with higher concantrations in bermudagrass vs bahiagrass pastures. Based on a critical level of 19 ppm in soil (Conrad et al., 1980), Fe

concentrations during the wet and dry seasons are adequate for plant growth. Iron content of herbage plants is a reflection of the species and the type of soil in which the plant grows (Underwood, 1966). Mean extractable soil Fe values were 19.7 and 20.5 ppm during the wet and dry seasons, respectively. Sanchez (1976) reported that 20 ppm Fe in soil was sufficient to prevent Fe deficiencies in crop. Extractable soil Fe values of about 14 ppm in the wet season and 16 ppm in the dry season have been reported in some Brazilian soils (Sousa, 1978) and values of 12 ppm have been reported in Florida (McDowell et al., 1982). Of all soil samples analyzed, 58 and 50% were deficient in Fe during the wet and dry seasons, respectively. Mean forage Fe levels were 55 and 80 ppm in the wet and dry seasons, respectively

Extractable soil Mn concentrations in the wet and dry seasons were 3.5 and 3.6 ppm, respectively. Soil Mn concentrations differed ($P < .001$) among locations, with higher values in bermudagrass vs bahiagrass pastures; however, there were no seasonal variations. Dantas (1971) suggested that 22 ppm of extractable soil Mn is sufficient for plant growth. On this basis, Mn levels were not adequate. All samples analyzed were deficient in Mn based on a critical level of 15 ppm (Conrad et al., 1980).

Forage Mn concentrations ranged from 62 to 82 ppm between the wet and dry seasons and from 10 to 103 ppm among locations. Mean forage Mn concentrations were 66 and 72 ppm during the wet and dry seasons, respectively. Both values (wet and dry season) exceed the estimated requirement of 40 ppm for beef cattle (McDowell et al., 1984). Manganese forage concentrations were extremely variable. This

variation reflects substantial species differences as well as soil and fertilizer effects (Underwood, 1977).

The solubility of Zn is highly pH dependent and decreases 100-fold for each unit increase in pH (Lindsay, 1972). Zinc deficiency induced in acid soils by overliming can easily be explained by this pH dependent relationship (Lindsay, 1972). Mean extractable soil Zn levels were .65 and .81 ppm during the wet and dry seasons, respectively, and ranged from .46 to 1.40 in the four locations. Sanchez (1976) indicated that critical level of soil Zn content for plants was 1.5 ppm and this value was associated with concentration of 14 ppm Zn in plant tissues. By this criterion, soil Zn was not adequate in the four locations. Of all samples analyzed for Zn, 98 and 100% were deficient based on a critical level of 1.5 ppm (Sanchez, 1976). No differences ($P > .05$) were found between seasons; however, soil Zn differed ($P < .01$) among locations.

Mean forage Zn levels were 21.3 and 27.5 ppm during the wet and dry season, respectively, and ranged from 16.6 to 33.5 ppm in the four locations. Of all samples analyzed, 85 and 63% were deficient in Zn during the wet and dry seasons, respectively, based on a critical level of 30 ppm (McDowell and Conrad, 1977). McDowell et al. (1978) stated that in recent years Zn deficiency in grazing animals has been reported in a number of countries when the Zn content of the diet was less than 40 ppm. McDowell et al. (1982) reported Zn was low (< 1.5 ppm) in 57.5% of all soil samples and deficient (< 30 ppm) in 89.5 and 80% of forage samples in Florida during the wet and dry seasons, respectively. From the present study, both soils and forages showing high percentage of Zn deficiency. Conditions such as high N and P

content of soils have also been reported to decrease Zn uptake by plants (Sharma et al., 1968).

Mean extractable soil Se concentrations were .042 and .046 ppm during the wet and dry seasons, respectively, and ranged from .040 to .048 ppm among the four locations. Cary et al. (1967) indicated that soil Se concentrations of less than .6 ppm are found in areas where Se deficiency in livestock occurs. Based on this critical level (<.6 ppm), all samples were extremely deficient in Se. The Entisols of Florida contained more soluble Se than in any other soil. Similarly, the leaching of Se in Entisol was higher than other soils (Cary et al., 1967). The authors concluded that Entisols are predisposed to contain deficient levels because of the high solubility and high leaching of Se in these soils. Also from Florida, McDowell et al. (1982) reported similar low levels of soil Se, ranging from .020 to .036, with all samples containing considerably less than the critical level (< 6 ppm). Forage Se was higher during the wet season (.037 vs .026 ppm for the dry season) with differences ($P < .001$) among locations. All samples analyzed were not adequate in relation to requirement of .1 ppm (NRC, 1976) and were deficient (< 1 ppm) during both seasons. Similar forage Se values were reported by Shirley et al. (1966) and McDowell et al. (1982).

Forage correlation

The correlation coefficients in forages are presented in appendix table 61. Correlation coefficients greater than or equal to $\pm .5$ at a probability level of .05, were as follows: Fe negatively correlated with Cu at the probability level of .001 and an r value of - .512 and Mn positively correlated with Mn at the probability level of .001 and

an r value of .502. The other minerals did not correlate with each other to meet the criterion ($r \geq .5$, $P = .05$).

Soil correlations

Correlation coefficients between soil parameters (appendix table 52) were generally smaller than those reported by Sousa (1978) in Brazilian soils. Considering only correlation coefficients greater than or equal to ±.5 at the significance level of .05, Cu positively correlated with P and Al at the probability level of .001 and the r values of .767 and .746, respectively. Extractable soil Fe positively correlated with P, Al and Cu at the probability level of .001 and the r values of .592, .689 and .874, respectively. Extractable soil Mn positively correlated with P, Al, Cu and Fe at probability level of .001 and the r values of .738, .657, .638 and .665, respectively. Extractable soil Zn positively correlated with P, Al, Cu and Mn at a probability level of .001 and the r values of .604, .619, .505 and .627, respectively. Extractable soil Ca positively correlated with Zn at a probability level of .001 and an r value of .624.

Trace Element Tissue Concentrations

Mean analysis of serum, feces, liver, and hair by treatment are presented in tables 16 and 22 and appendix tables 46 and 47 with analysis by period in tables 17, 18, 20, and 21, respectively. Analysis of variance-mean squares for liver, calf serum, cow serum, feces and hair are presented in appendix tables 32, 34, 35, 38, and 39, respectively. Appendix table 50 presents tissue mineral concentrations of the wet vs the dry season. Seasonal differences ($P = .05$) were found with liver Co, Cu, Fe, and Mo and serum Fe higher in the wet season and serum Se fecal Cu, Se, and Zn and hair Fe, Mn

TABLE 17. COW AND CALF SERUM TRACE ELEMENT CONCENTRATIONS AS AFFECTED BY PERIODS

Parameter*	Drill rel* level	Animal class	Sampling Periods** P_1 (5/80) Mean	% Def	P_2 (10/80) Mean	% Def	P_3 (7/81) Mean	% Def	P_4 (5/81) Mean	% Def	P_5 (10/81) Mean	% Def	P_6 (7/82) Mean	% Def	Overall Mean Mean	% Def	Standard error range
Serum (ppm)																	
Cu	.65	cow	86[a]	0	88[a]	0	98[a]	0	1.28[b]	2	1.21[b]	0	83[a]	0	1.04	6	.020 .011
		calf			1.66[a]				.71[c]	38	1.16[b]				.97	13	.075 .111
Fe		cow	2.88[a]		2.15[a]		1.11[c]		1.56[b]		1.27[b]		1.43[b]		1.66		.091 .091
		calf															
Se	.03	cow	.087[a]	100	.010[e]	81	.056[b]	28	.014[ac]	11	.025[d]	46	.012[d]	20	.030	65	.001 .011
		calf			.029[a]	65			.014[b]	100	.013[b]	95			.019	86	.002 .008
Zn	1	cow	.85[a]	45	1.64[a]	1	1.27[ac]	7	1.52[b]	0	1.21[ac]	0	1.09[a]	9	1.26	9	.057 .057
		calf			2.09[a]	1			1.43[c]	0	1.10[bc]	0			1.54	6	.113 .146

*15 means are based on the following number of samples: cows 36, 36, 37, 31, 36, and 32; calves 28, 36, and 36 for periods 1-6 for cows and 2, 4, and 6 for calves, respectively

McDowell 1976; McDowell and Conrad, 1981

**Serum was collected from cows four times during the wet (June-October) season and twice during the dry (November-May) season. Periods 3 and 6 fall within the dry season while the rest are within the wet season

a,b,c,d,eMeans in the same row with different superscripts differ (P < .05)

TABLE 18. FECES MINERAL CONCENTRATIONS AS AFFECTED BY PERIODS.

Parameter[a]	Periods[c] P3 (2/81)	P4 (6/81)	P5 (10/81)	P6 (3/82)	S.E.R.[b]
Cu, ppm	15.23[e]	14.42[e]	9.61[f]	33.30[d]	1.01-1.81
Se, ppm	.087[d]	.062[e]	.038[f]	.072[d]	.005-.081
Zn, ppm	82.0[h]	87.3[hi]	53.1[i]	72.0[j]	1.87-1.96

[a]LS means are based on the following number of samples: 34, 32, 33, and 31 except for Se (31, 30, 27, 22) for periods 3, 4, 5 and 6, respectively.

[b]Standard error range.

[c]Fecal samples were collected twice during wet (June-October) and dry (November-May) seasons.

[d,e,f,g]Means in the same row with different superscripts differ ($P < .001$).

[h,i,j]Means in the same row with different superscripts differ ($P < .001$)

and Se higher in the dry season. Differences among treatments were found for liver, feces, and hair Se ($P < .001$) and for serum Fe and Se and fecal Cu and Zn ($P < .05$). Period x treatment interactions ($P < .001$) were found only for liver Se.

Liver Co differed ($P < .001$) among periods of collection and ($P < .05$) between seasons. Mean liver Co levels were .53 and .43 ppm during the wet and dry seasons, respectively, with higher ($P < .05$) values during the wet season. Liver Co concentration has been reported to be a good indicator of the Co status of grazing animals, with levels below .05 ppm considered as a critical concentration. All analyzed samples were above critical level of <.05 ppm (McDowell and Conrad, 1977). Forage and soil Co showed 17 and 100% deficient levels, respectively, however, liver Co was adequate (<.05 ppm) for beef cattle. McDowell et al. (1982) reported similar Co concentrations. The most likely explanation for this is the large amount of Co found in free choice mineral supplements.

Liver Cu was higher ($P < .05$) during the wet season (317 vs 250 ppm for dry season), with no seasonal effect ($P > .05$) observed in hair Cu and Mo and serum Cu concentrations. However, fecal Cu was higher ($P < .01$) during the dry season (24.3 vs 12.0 ppm for wet season). Mean liver Mo levels were 3.43 and 2.76 ppm for the wet and dry seasons, respectively, with higher values ($P < .05$) during the wet season. Mendes (1977), in Brazil, reported higher ($P < .05$) liver Mo in the rainy vs dry season. No differences ($P > .05$) were found among treatments in liver, serum, and hair Cu, while fecal Cu differed ($P < .01$) among treatments with higher values in treatment 3 (high mineral supplement) than in treatment 1 (control); however, the

diffnrence between treatment 2 and 3 was not significant. Available information indicates that feces are the main means of excretion of Cu, while low urinary excretion of Cu has been reported (Conar et al., 1948; Smith et al., 1968).

Copper deficiency in animals is reported to be caused by many known and unknown factors and is complicated by the absence of a direct relationship between incidence of Cu deficiency in animals and concentrations of Cu in forages and soils (Underwood, 1966). Overall mean Cu concentrations during the wet and dry seasons were normal compared to the suggested critical level of <75 ppm for liver (Cunha et al., 1964) and < 65 ppm for serum (McDowell, 1976). All samples analyzed for liver Cu were above the critical level of <75 ppm. Mean liver Mo contents are in agreement with the approximate normal level of 2 to 4 ppm indicated by Underwood (1977) which suggests that Mo was not present in high enough concentrations to interfere greatly with Cu metabolism. Of all calf serum samples analyzed for Cu, only 13% were below the critical level of <=65 ppm.

Treatment difference ($P < .05$) was found only for serum Fe with values higher in treatments 2 and 3 (Se and high mineral supplements). No difference ($P > .05$) was found between treatments in serum, liver, and hair Mn. Seasonal differences ($P < .05$) were found with liver and serum Fe higher in the wet season and hair Fe and Mn higher in the dry season. Mean seasonal liver Fe and Mn concentrations were above the critical levels of 180 and 6 ppm, respectively (McDowell and Conrad, 1977). Cunha et al. (1964) indicated 200 to 300 ppm as the normal level of Fe in cattle liver. Based on the critical level of 180 ppm, incidence of Fe deficiencies was low (3%). Mean hair Fe and Mn in the

TABLE 19. COW AND CALF SERUM TRACE MINERAL CONCENTRATIONS AS AFFECTED BY TREATMENT

Parameter*	Critical+ level	Animal class	Mineral Supplementation T_1 Mean	T_1 % Def	T_2 Mean	T_2 % Def	T_3 Mean	T_3 % Def	Standard error range
Serum (ppm)									
Cu	.65	cow	1.03	2	1.07	0	1.05	0	.008-.02
		calf	.94	5	.83	24	.99	10	.026-.030
Fe		cow	1.51		1.58		1.65		.059-.062
		calf							
Se	.03	cow	.024[b]	81	.055[a]	52	.045[ab]	62	.007-.009
		calf	.015	90	.020	81	.019	84	.001-.002
Zn	.8	cow	1.24	5	1.30	11	1.24	2	.038-.040
		calf	1.36[b]	0	1.73[a]	0	1.72[a]	0	.12-.13

*LS means are based on the following number of samples: cows, 66, 69, and 66, calves 35, 34, and 31 for treatments 1, 2, and 3, respectively.

+McDowell, 1976, McDowell and Conrad, 1977.

T_1, T_2, and T_3 are control, control plus Selenium and fortified mineral supplements, respectively.

[a,b]Means in the same row with different superscripts differ ($P < .06$).

TABLE 20 LIVER MINERAL CONCENTRATIONS (DRY BASIS) AS AFFECTED BY PERIODS

Parameter[a]	Critical[c] level	Sampling Period[d,g] P 1 (9/80) Mean	% Def	P 2 (10/80) Mean	% Def	P 3 (2/81) Mean	% Def	P 4 (9/81) Mean	% Def	P 5 (10/81) Mean	% Def	P 6 (3/81) Mean	% Def	Overall Mean Mean	% Def	S E a[b]
Livee (ppm)																
Co	05	49[i]	0	82[e]	0	34[g]	0	39[g]	0	61[e]	0	92[i]	0	93	0	21 99
Cu	79	229[j]	5	391[j]	0	251[j]	0	206[i]	0	269[j]	0	248[i]	5	299	0	104 132
Fe	140	184[g]	7	915[c]	0	527[f]	0	549[f]	0	549[f]	0	999[c]	5	917	3	296-306
Mn	5	9 9[i]	5	15.3[k]	0	12.6[j]	0	11 2[j]	5	9 7[j]	10	8 5[j]	15	11 2	5	3 1-3 5
Mo	5	2 02[j]	5	3 96[i]	13	3.23[i]	0	2 98[j]	9	3 99[i]	0	3.35[k]	0	3 11	5	01 99
Se	29	19[g]	100	29[g]	30	27[g]	5	56[e]	29	39[f]	13	90[c]	30	97	9[h]	11-55
Zn	94	100[i]	62	155[i]	10	109[i]	5	52[m]	10	100[i]	7	68[m]	27	103	17	19 2 29 5

[a] LS means are based on 19e following number of samples: 31, 38, 25, 21, 29, 29 for periods 1-6, respectively.

[b] Standard error range

[c] McDowell, 1979; McDowell and Conrad 1977.

[d] Lane samples were collected four times during wet (June October) season and twice during 19e Dry (November-May) season. Periods 3 and 5 fell within 19e Dry season while the rest are within the wet season.

[e, f, g, h] Means in the same row with 5ifferent superscripts 5iffer (P < 001)

[i, j, k] Means in 19e same row with 5ifferent superscripts 5iffer (P < 01)

[l, m] Means in 19e same row with 5ifferent superscripts 5iffer (P < 05)

TABLE 21 EFFECT OF PERIODS ON HAIR TRACE MINERAL CONCENTRATIONS

Parameter[a]	Sampling periods[c] P_1 (5/80)	P_2 (10/80)	P_3 (2/81)	P_4 (6/81)	P_5 (10/81)	P_6 (3/82)	S E R[b]
Hair (ppm)							
Cu	6.68[d]	7.93[e]	6.91[d]	6.25[d]	6.14[d]	7.33[de]	33- 38
Fe	130[d]	46[e]	232[f]	161[g]	79[h]	159[dg]	10.4-12.2
Mn	6.94[d]	4.50[g]	6.08[fg]	9.92[d]	5.68[eg]	12.64[e]	.77- 90
Mo	.109[i]	.115[i]	.101[i]	130[ik]	083[j]	144[k]	008- 010
Se	094[e]	076[e]	599[d]	186[fg]	.143[f]	.206[g]	.010- 31
Zn	75[d]	95[e]	86[ef]	78[df]	94[e]	87[eg]	3.20-3.57

[a]LS means are based on the following number of samples 36, 35, 31, 32, 36, and 28 except for Se (33, 28, 30, 27, 25, and 26) for periods 1-5, respectively.

[b]Standard error range.

[c]Hair samples were collected four times during wet (June-October) season and twice during the dry (November-May) season. Periods 3 and 5 fall within the dry season, while the rest are within the wet season.

[d,e,f,g,h]Means in the same row with different superscripts differ ($P < .001$).

[i,j,k]Means in the same row with different superscripts differ ($P < .01$).

TABLE 22. FECES MINERAL CONCENTRATIONS AS AFFECTED BY TREATMENT

Parameter[a]	Treatment T_1	T_2	T_3	S.E.R.[b]
Cu, ppm	15.4[e]	19.2[d]	19.6[cd]	.880-1.02
Se, ppm	.041[h]	.077[i]	.058[ij]	.053-.056
Zn, ppm	57.5[f]	60.5[fg]	64.9[g]	1.62-1.83

[a] LS means are based on the following number of samples: 44, 45, and 41 for treatments 1, 2, and 3, respectively.

[b] Standard error range.

T_1, T_2, and T_3 stand for control, control plus Selenium, and fortified minerals, respectively.

[c,d,e] Means in the same row with different superscripts differ ($P < .01$).

[f,g] Means in the same row with different superscripts differ ($P < .05$).

[h,i,j] Means in the same row with different superscripts differ ($P < .001$).

wet and dry seasons ranged from 46 to 232 and 5.7 to 12.6 ppm, respectively. McDowell et al. (1982) reported that hair Mn was negatively correlated ($P < .001$, $r = -.36$) with liver Mn, indicating that hair is not a good indicator of Mn status. Hartmans (1974) found no difference ($P > .05$) in hair Mn when identical twin cattle were fed either 21 or 130 ppm Mn.

No seasonal differences ($P > .05$) were found in liver, serum, or hair Zn. However, fecal Zn differed ($P < .05$) between seasons with high values in the dry season (55.2 vs 47.0 ppm). Miller et al. (1966) reported that high fecal Zn may denote a high Zn intake and, thus, animals with low Zn intake have reduced Zn excretion. Except where massive amounts of Zn are fed either intentionally or accidentally, it appears unlikely that too much Zn would be a practical problem (Miller, 1981). Among tissues analyzed for Zn, there were no differences ($P > .05$) between seasons with exception of fecal Zn which was higher ($P < .01$) in the dry than in wet season. Mean liver Zn varied from 103 to 99 ppm in the wet season and dry season, while mean serum Zn values were 1.3 and 1.2 ppm during the wet and dry seasons, respectively. All mean liver Zn values were within the range of 84 to 150 ppm Zn reported in beef cattle livers by Powell et al. (1964) and E.R. Miller et al. (1966). In contrast to forage Zn, serum Zn only showed 11 and 8% deficiency compared to 85 and 63% in forage during the wet and dry season, respectively. According to CMN (1973), blood plasma is the best indicator of Zn status in grazing animals with levels below .4 ppm suggesting Zn deficiency. Of all liver samples analyzed, only 22 and 16% had critical Zn concentrations (< 8 ppm) in the wet and dry season, respectively. Levels of some

trace elements in hair may be correlated with dietary intake or mineral status of animals (Combs et al , 1982) Combs et al (1983) reported that, in experimental rats, Zn content of hair ($P < .01$) increased (204 to 254 ug/g) linearly as levels of dietary Zn increased from 10.3 to 52.9 ug Zn/g diet.

Hair, fecal, and serum Se concentrations were higher ($P < .01$) during the dry season, while there were no seasonal differences ($P > .05$) in liver Se. Mean liver Se values were .38 and .35 ppm in the wet and dry seasons, respectively. McDowell et al. (1978) indicated that critical Se levels in the liver of cattle are usually between .25 to .50 ppm on a dry matter basis, while values on the order of 5 and 15 ppm are suggestive of excessive Se intake. On this basis, mean liver Se levels reported in the present study were low during both seasons, especially period 1 (initial period) where all samples were deficient. From Florida beef ranches, McDowell et al (1982) reported liver Se concentrations were below the critical level (<.25 ppm) in 32 and 39% of the samples in the wet and dry seasons, respectively. Mean serum Se contents were .021 and .054 ppm in the wet and dry seasons, respectively. Based on a critical level of .03 ppm, 73 and 20% of serum analyzed for Se were deficient during the wet and dry seasons, respectively. Mean hair Se concentrations were .125 and .403 ppm in the wet and dry seasons, respectively. Hidiroglou et al. (1965) found that cows with hair Se values ranging from .06 to .25 ppm produced calves with white muscle disease (WMD), while cows with hair Se higher than .25 ppm had normal calves. Hair Se was deficient (<.25 ppm) in the wet season, but adequate in the dry season. Mean

fecal Se was .049 ppm in the wet season and .080 ppm in the dry season

Liver, serum, feces, and hair Se differed ($P < .001$) among treatments, with highest levels in treatments 2 and 3. Perry et al. (1976) reported that tissue concentration of Se increased as the daily intake of Se increased, regardless of tissue sampled. Whanger et al. (1977) reported that vitamin E alone is more effective in prevention of white muscle disease (WMD) than Se alone. In contrast to vitamin E, Se alone did not maintain the activity of plasma enzymes (LDH, SGOT, ALK and SGPT) at low levels. Calf serum Se differed ($P < .05$) among treatments with higher levels in treatments 2 and 3, which reflected the higher dietary Se status of their dams. It appears that blood serum Se levels may reflect both dietary levels or tissue storage levels of this element. Perry et al. (1976a, 1976b) reported that an increase in dietary Se would result in increased serum Se levels in 7 to 14 days. Perry et al. (1978) reported that elevated calf serum Se levels from cows fed higher Se levels indicated Se crosses the placental membrane. Liver, serum, hair, and fecal Se levels generally increased with later periods indicating a buildup effect as the experiment progressed

Milk and Colostrum Trace Elements

Mean milk and colostrum Cu, Fe, Mn, Mo, Se and Zn concentrations as affected by period are presented in table 23 and by treatment in appendix table 37. Seasonal differences ($P < .05$) were found, with milk Cu, Fe and Mn higher in the wet season and Mo and Se higher in the dry season. Milk Fe and Mn were higher ($P < .05$) in treatments 2 and 3, while milk and colostrum Se concentrations were higher

TABLE 23. EFFECT OF PERIOD ON MILK AND COLOSTRUM TRACE MINERAL CONCENTRATIONS

Sampling Period*	Cu	Fe	Mn	Mo	Se	Zn
Milk (ug/ml)						
P_1 (5/80)	,43[a]	1 11[a]	,12[a]	.029[b]	,004[c]	4.31
P_3 (2/81)	.30[b]	.86[b]	.05[b]	.026[b]	.010[a]	4 13
P_4 (6/81)	.27[b]	.50[c]	.07[b]	.021[c]	.007[b]	4.34
P_6 (3/82)	,35[c]	.60[c]	.11[e]	.055[a]	,007[b]	3.67
S.E. Range[+]	.06-,13	.15-,21	.002-,005	.005	.001-.004	,13-.16
Colostrum (ug/ml)						
P_3 (2/81)	.51	1.07	,06	.031	.045[d]	14.56
P_6 (3/82)	.47	1 00	06	038	.020[e]	16.17
S.E. Range[+]	.03	.05	.009	.0037	.002-.004	.774

*LS means are based on the following number of samples: milk, 34, 25, 25, and 28 for periods 1, 3, 4, and 6, colostrum, 36 and 35 for periods 3 and 6, respectively

[+]Standard error range.

[a,b,c]Means in the same column with different superscripts differ (P < .05),

[d,e]Means in the same column with different superscripts differ (P < .01).

(P < .001) in treatment 2 (high in Se). The everege for treetment 2 end 3 over time showed milk from those cows (receiving Se supplement) had more (P < .01) Se in milk than milk from cows fed no Se supplement (control). Milk from control cows contained an average of .004 ug/ml, whereas samples from the treated cows contained .009 and .006 ug/ml for treetments 2 end 3, respectively. By plotting everege daily Se intake vs average milk Se concentration, Perry et al. (1977) indicated thet there was close correlation between increased total daily Se intake and Se in milk

Relationship of Minerals in Animal Tissues

Correlation coefficients in animal tissues ere presented in appendix table 53 and those between animal tissues and forage in eppendix table 54. Soil, forege end enimal tissues were not computed because enimals grazed communally. Such correlation coefficients have been found to be small or nonexistent (Conrad et al., 1980). Liver and serum showed no correlation coefficients greater than or equal to +.5 et the probability level of .05.

Correlation Coefficients Between Animal Tissues end Forege Parameters

Fecal Zn positively correlated with forege Zn et probability level of .01 and the r value was .531. Hair Zn was negetively correlated with forege Mg and K et probability level of .01 end the r values were -.544 and -.514, respectively. Hair Cu negetively correlatad with forage K at the probability level of .01 and the r value was -.507. Hair Mn positively correleted with forege Mn et probability level of .01 end the r veiue wes .503. Liver Cu positively correlatad with forage Zn et probability level of .01 and tha r valua was .517.

Summary

An experiment was conducted to determine the trace mineral status of grazing Brahman cows as affected by treatment and season of the year. Liver biopsy, bone biopsy, hair, blood, feces, milk, forage, and soil samples were collected for mineral analyses during wet (June-October) and dry (November-May) seasons.

For each soil trace mineral analyzed, no differences ($P > .05$) were found between seasons. However, seasonal differences ($P < .05$) existed in all forage trace minerals with exception of Cu and Co. Seasonal differences ($P < .05$) were found with liver Co, Cu, Fe, and Mo and serum Fe higher in the wet season and serum Se, fecal Cu, Se, and Zn and hair Fe, Mn and Se higher in the dry season. Differences among treatments were found for liver, feces, and hair Se ($P < .001$) and for serum Fe and Se and fecal Cu and Zn ($P < .05$).

Forage and liver analyses showed adequate concentrations of Fe and Mn, with no excess of Mo. However, the majority of extractable soil Fe and Mn were below the critical levels. In both seasons, extractable soil Co was deficient with forage and liver Co concentrations within normal levels. Although above critical concentrations in liver and serum, Cu was low in forage and soil during both seasons. Hartmans (1974) previously found no relationship between soil or forage Cu concentrations and Cu status in cattle.

In general, Fe and Mn analysis indicated adequate concentrations. Of the trace minerals normally supplied in mineral supplement mixtures, Fe and Mn are least likely to be deficient for grazing cattle.

Forage and soil Zn analyses in the wet and dry seasons indicated deficient concentrations, while tissue levels were generally adequate. Dnring the wet season, forage Cu and Zn were low in 85% of samples, while extractable (donble acid) Ca, Fe, Mn, Zn and Co were low in 63, 65, 100, 88 and 100% of soils, respectively In the dry season, 100 and 63% of forages were low in Cu and Zn, respectively

The most pronounced findings from the analyses of samples was the low Se status of pastures soils and animal tissues. In all samples analyzed, Se was deficient in both the wet and dry seasons On the basis of Se analysis, combined dietary and injectable Se-vitamin E resulted in higher tissue levels Of the seven trace minerals studied, Cu, Mn, Zn, Co and Se in soil, Ca, Se and Zn in forages, and Se in animal tissues are most likely to be deficient. Mineral supplementations improved Zn and Se status of the animals compared to the initial period. The finding in this study is in agreement with the report by McDowell et al (1982) that the inadequate Se status observed, plus persistent reports of white muscle disease in the state, emphasize the need for increasing dietary intake of Se.

CHAPTER VI
EFFECT OF MINERAL SUPPLEMENTATION ON BLOOD MINERALS AND METABOLIC PROFILES IN BRAHMAN CALVES

Introduction

Metabolic profiles have been used to diagnose existing disease problems or to monitor health status in a general herd program. Research to evaluate health status in dairy herds has successfully been based on metabolic profiles (Payne et al., 1970, McAdam and O'Dell, 1982). Also, blood parameters in feed lot cattle have been calculated in an attempt to discover and diagnose herd health problems in beef cattle. There is a lack of published "normal" values for Brahman calves at birth and at later stages of development. Collins (1976) and Franks (1973) published results of blood analysis for Brahman calves in an effort to establish "normal" values for some blood components. Auto analyzers are now available to perform multiple blood component assays on a single sample. Examples are sequential multiple analyzers (SMA) and sequential multiple analyzers with computer (SMAC). According to the scientific literature, the majority of blood components in cattle fall within the ranges found in human blood (Collins, 1978). Adams et al. (1978) reported that a number of factors limit the usefulness of blood metabolic profiles. These include sampling problems, low correlations with nutrient intake, inconsistent pattern in diseases and difficulties in interpretation.

Calf crops weaned in beef herds in Florida are the lowest in the continental U.S.A., excluding Alaska. Causes for low calf crops among

Brahman herds are 1) weak calves at birth, 2) calves with abnormal nursing response, and 3) calves that failed to survive for various reasons beyond 3 days of age.

Studies reported herein were designed to 1) compile data of blood profiles for Brahman calves at birth, 3 days and 3 months of age, 2) evaluate the possibility of correlation between dam's mineral supplementation (Selenium, dietary and injected, and fortified minerals) and calf vigor and nursing response, and 3) establish the validity of use of blood metabolic profiles as a reliable diagnostic tool for Brahman calf viability during the first days of life.

Experimental Procedure

The experiment was conducted at University of Florida Pine Acres Purebred Beef Research Farm located in central Florida. The soil (Entisol) was sandy and well drained and pastures were exclusively bermudagrass (Cynadon dactylon) and bahiagrass (Paspalum notatum). The experimental units were comprised of 36 registered Brahman cows (4 to 10 years old) in early pregancy. Cattle were allotted randomly to 3 treatments of 12 cows per treatment as follows: control, high in Se, and fortified mineral supplements.

Milk and serum samples were collected for mineral analysis from 36 cows twice (at parturition and 3 months postpartum) in years 1981 and 1982. Serum was collected from 60 calves (30 per calf crop) for blood metabolic profiles three times (at birth, 3 days and 3 months of age) in years 1981 and 1982. Methods of collection have been described by Fick et al. (1979) and in Chapter IV.

Cows were kept under strict surveillance. Once a calf was born, an individual record was filed which recorded time of birth, sex,

birth weight, date of birth, description of calf, rectal temperature, nursing ability, vigor of calf, and treatment given. Calves used in this experiment did not nurse before the first sample (serum) was taken and were allowed to nurse colostrum for three days before the second sample was taken.

Calves were restrained and a 15 ml vacutainer tube (no anticoagulant) of blood was drawn from the jugular vein. This blood was allowed to clot in a cool place for about 15 minutes. When the clot was achieved, serum was separated from whole blood in a centrifuge by spinning for 10 minutes at 3500 rpm. Serum was drawn and frozen in clean sterile tubes. Samples were analyzed according to methods described by Collins (1978) at the Smith-Kline Clinical Laboratories. A sequential multiple analyzer with computer (SMAC 24) automated system was used for the analysis. Procedures for serum mineral analysis have been described (Fick et al., 1979). Serum was analyzed for P, Ca, Mg, Fe, Cu, Zn, and Se. Hemoglobin (Hb) was determined by modification of colorimetric method (Martinek, 1970) and packed cell volume (PCV) by the microhematocrit method.

Milk and colostrum samples (20 and 15 ml, respectively) were dried overnight in an oven at 60° C, then ashed overnight in a muffle furnace at 550° C. Solutions of milk and colostrum were prepared and analyzed for Ca, P, Mg, K, Fe, Cu, Zn, Mn, Mo and Se according to Fick et al. (1979).

Data were statistically analyzed according to split-plot design (Steel and Torrie, 1960). Data were analyzed by General Linear Model (GLM) procedure of Statistical Analysis System (SAS)(Barr et al., 1973) by analysis of variance to test for significance among

treatments, duration of the experiment, calf crop, and their interactions.

Result and Discussion

Serum Mineral Contents of Cows

Serum mineral concentrations as affected by physiological state of cows (postpartum vs lactating cows) are presented in table 24. Appendix tables 55 and 56 presenting the affect of duration of the experiment and treatment, respectively. Appendix table 55 presents analysis of variance-mean squares serum data. Mean serum Ca, Mg, P, and PCV were higher ($P < .05$) at parturition than at three months of age. Low mineral concentrations at three months after onset of lactation could be due to secretion of minerals in milk and an increased nutrient requirement. No differences ($P > .05$) were found in serum Zn and Se between physiological state groups (at parturition and 3 months postparturition); however, serum Cu was higher ($P < .05$) at three months postparturition. Crop x time interactions ($P < .01$) were found for serum P, Mg, Cu, Zn and Se.

Mean serum Ca and Hb differed ($P < .01$) between years 1981 and 1982 with higher values in year 1982 while Cu was higher ($P < .05$) in year 1981. Serum Ca, Mg, Zn, and Se increased in concentrations with time indicating a buildup effect as the experiment progressed. Parry et al. (1976) reported a similar result in which Se increased ($P < .05$) with time.

No differences ($P > .05$) among treatments were obtained for serum minerals except for Se, with higher ($P < .001$) levels in treatments 2 and 3 (Se and fortified mineral supplements, respectively). Parry et al. (1976) reported that tissue concentration of Se was increased as the dietary intake of Se was increased, regardless of tissue sampled

TABLE 24. HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM MINERAL COMPOSITION OF COWS AT PARTURITION AND THREE MONTHS LATER.

Period[a]	Ca mg/100 ml	Mg mg/100 ml	P mg/100 ml	Cu ug/ml	Zn ug/ml	Se ug/ml	Hb %	PCV %
Parturition[b]	9.31[d]	2.60[f]	4.39[f]	.956[h]	1.41	.058	12.9	38.7[h]
After 3 mo.	8.08[e]	2.40[g]	4.21[i]	1.143[g]	1.45	.063	13.3	36.2[i]
S.E.M.[c]	.175-.186	.047-.050	.156-.167	.026-.028	.001-.006	.002-.004	.151-.153	.432-.440

[a]LS means are based on the following number of samples: 68 and 66 for parturition period and after 3 months, respectively.

[b]Brahman cows were sampled at parturition and three months later in years 1981 and 1982.

[c]Standard error of the mean.

[d,e]Means in the same column with different superscripts differ ($P < .001$).

[f,g]Means in the same column with different superscripts differ ($P < .05$).

[h,i]Means in the same column with different superscripts differ ($P < .01$).

Minaral Contents of Milk and Colostrum

Mean milk and colostrum minaral concantrations are presantad in table 25. Analysis of variance-mean squares milk data are presantad in appandix table 56. Colostrum was higher ($P < .01$) in Mg, P, Cu, Fe, Sa and Zn than in milk (220 vs 61 ug/ml, 13 vs 09%, .48 vs 32 ug/ml, 1.1 vs .51 ug/ml, .032 vs .007 ug/ml and 15.4 vs 4.2 ug/ml, raspactivaly), whila milk was higher ($P < .001$) in Mn vs colostrum (.06 vs .09 ug/ml). Time x treatment interactions ($P < .05$) were found with milk and colostrum P, Sa, and Zn and crop x time x treatment interactions were found for P and Se. Akinsoyinu (1981) studied Ca and P in milk and blood serum of lactating Red Sokoto goats and found colostrum contained more Ca and P (141 and 118 mg/100 ml, respectively) than regular milk (130 and 93 mg/100 ml, respectively).

Mean mineral contents as affacted by treatment are presented in appandix tabla 57. Diffarances among traatments wara found only in milk Se and Fe. Se was higher ($P < .001$) in treatments 2 and 3 than in 1 (Se supplement vs control) with Fe highar in treatment 1 than in 2 and 3. However, in cows, sows and goats, Fa and Cu supplementation does not appreciably affect milk Fe and Cu contents (Archibald, 1958) in dairy animals, Zn (W.J. Miller et al., 1965), Mn (Archibald, 1958), and Sa (Parry at al., 1977) contents of milk can ba incraasad by dietary supplemantation.

Milk minaral concentrations as affected by duration of experiment are presented in appandix table 58. Milk Mo was higher ($P < .001$) in yaar 1982 than in 1981 indicating highar milk concentrations as tha experiment progressed. In contrast to milk Mo, milk Sa was highar

TABLE 25. MILK MINERAL COMPOSITION AT PARTURITION (COLOSTRUM) AND THREE MONTHS LATER.

Period	Ca %	Mg mg/ml	K %	P %	Cu ug/ml	Fe ug/ml	Mn ug/ml	Mo ug/ml	Se ug/ml	Zn ug/ml
Parturition[a]	143[e]	220[c]	592	127[e]	432[e]	1 000[e]	769[c]	033	032[c]	15 42[c]
After 3 mo	128[f]	91[d]	597	090[f]	316[f]	506[f]	003[d]	041	007[d]	8 23[d]
S.E.E.[b]	002-.003	6 43-12 3	.002-.003	.001-.002	.023-.025	.034-.037	.005-.007	.004-.006	.004-.007	.434-3.12

[a] LS means are based on the following number of samples: 79 and 55 for parturition period and 3 months later, respectively.

[b] Standard error range

[c-d] Means in the same column with different superscripts differ (P < .001)

[e-f] Means in the same column with different superscripts differ (P < .01)

($P < .001$) in year 1981 than in 1982 which is in disagreement with the reported values indicating a buildup affect by time (Perry et al., 1976).

Calf Blood Metabolic Profiles

Mineral elements

Mean analysis of calf serum mineral elements by age are presented in tables 26 and 27 with analysis by calf crop in appendix tables 59 and 61 and analysis by treatment in appendix tables 60 and 62, respectively. Analysis of variance-mean squares calf serum and blood metabolic profile data are presented in appendix tables 63 and 64, respectively. Serum Ca, Mg, Cu, Se, Na, K, and Cl differed ($P < .001$) among age groups (at birth, 3 days and 3 months of age). Collins (1978) indicated that age ($P < .001$) affected both serum Ca and P levels. Both of these minerals decreased steadily with increasing age. All mineral values with exception of P, Mg and Se had a consistent trend. Values started at low levels, increased at 3 days and then decreased. Mogg (1961) indicated that there was a tendency for blood mineral composition values to be higher in Brahman calves at 3 days of age than at birth. This coincides with milk composition with most mineral values higher in colostrum than regular milk. Both serum Mg and Se decreased by age drastically to values below critical levels of .2 mg/100 ml and .03 ug/ml, respectively (McDowell et al., 1984), indicating that Mg and Se deficiencies are likely to increase with age. Milk Mg and Se showed also a rapid change in concentrations with higher levels ($P < .001$) in colostrum than in regular (3 month postparturition) milk (220 vs 61 ug/ml and .032 vs .007 mg/ml, respectively). Increasing Se intake of cows resulted in higher

TABLE 26. CALF HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV), AND SERUM MINERAL CONCENTRATIONS AS AFFECTED BY AGE.

Parameter[a]	Calf age[b]			Standard error range
	Pre	Post	3 mo.	
Ca, mg/100 ml	11.3[d]	13.0[c]	7.77[e]	.207-1.34
P, mg/100 ml	8.60	8.13	8.58	.150-.163
Mg, mg/100 ml	2.58[c]	2.38[d]	1.58[e]	.044-.086
Cu, ug/ml	.375[e]	.793[c]	.711[d]	.024-.046
Zn, ug/ml	1.41	1.53	1.50	.021-.032
Se, ug/ml	.086[c]	.030[d,e]	.015[e]	.006-.007
Hb, %	12.7	13.4	12.3	.263-.272
PCV, %	42.6	42.1	40.3	.862-.893

[a]LS means are based on the following number of samples: 58, 59, and 60 for pre-, post- and 3 mo., respectively.

[b]Serum samples were collected from calves at prenursing (pre), 3 days after nursing (post), and when they were 3 months old (3 mo.).

[c,d,e]Means in the same row with different superscripts differ ($P < .001$).

TABLE 27. CALF BLOOD METABOLIC PROFILES AS AFFECTED BY AGE.

Parameter[a]	Calf age[b] Pre	Fast	3 mo.	Standard error range
Glucose, mg/dl	76.7[e]	114.3[c]	92.6[d]	4.33-4.54
Na, meq/l	143[c]	143[c]	134[d]	.949-.966
K, meq/l	5.08[c]	5.30[d]	4.66[e]	.060-.063
Chloride, meq/l	102[c]	102[c]	98[d]	.682-.714
CO_2 content, meq/l	20.7[e]	21.6[d]	16.9[c]	.301-.315
Na-($Cl+CO_2$), meq/l	20.2[f]	15.2[g]	18.9[h]	.291-.305
BUN[g], mg/dl	12.7[c]	13.9[cd]	10.9[e]	.436-.458
Creatinine, mg/dl	2.25[c]	1.63[d]	1.26[e]	.073-.077
BUN/Creatinine ratio	6.08[g]	10.60[c]	8.78[d]	.368-.386
Uric acid, mg/dl	1.252[c]	.878[de]	.751[e]	.072-.075
Total protein, g/dl	4.68[e]	5.59[c]	5.23[d]	.115-.121
Albumin, g/dl	3.17[c]	3.00[c]	3.37[d]	.065-.069
Globulin, g/dl	1.58[de]	2.59[c]	1.86[d]	.122-.126
A/G[h] ratio	2.24[c]	1.48[d]	1.80[c]	.083-.087
Ionized Ca, mg/dl	5.58[c]	5.20[d]	4.17[e]	.118-.124
Bilirubin, total, mg/dl	.908[c]	.572[d]	.113[e]	.055-.058
Alkaline phosphatase, U/l	616[c]	757[c]	286[d]	75.2-78.8
LDH[j], U/l	644[e]	729[d]	994[c]	24.7-25.8
SGOT[k], U/l	51.8[c]	44.8[c]	32.4[d]	2.98-3.12
SGPT[k], U/l	18.7[d]	12.7[e]	28.9[c]	1.42-1.48
Cholesterol, total, mg/dl	39.7[c]	51.4[c]	200.4[d]	4.13-12.6
Triglycerides, mg/dl	10.4[e]	22.3[c]	17.4[d]	1.44-1.52
Fe, Serum, ug/dl	86[c]	106[c]	167[d]	8.37-12.5

TABLE 27-continued.

[a]LS means are based on the following number of samples 56, 54, and 58 for pre-, post- and 3 mo., respectively.

[b]Serum samples were collected from calves at prenursing (pre), 3 days after nursing (post), and when they were 3 months old (3 mo.).

[c,d,e]Means in the same row with different superscripts differ ($P < .001$).

[f,g,h]Means in the same row with different superscripts differ ($P < .01$).

[i]Blood urea nitrogen

[j]Albumin/globulin ratio.

[k]Lactic dehydrogenase

[l]Serum glutamic-oxalacetic transaminase.

[m]Serum glutamic-pyruvate transaminase.

($P < .05$) serum Se concentrations in their calves suggesting that Se crosses the placental membrane. However, due to low concentration of Se in milk, calf serum Se values decreased by age from .086 ug/ml at birth to .03 and .015 ug/ml at 3 days and 3 months, respectively. The values obtained for serum Fe were highly variable. These were 86 meq/dl at birth, 106 meq/dl at 3 days and 147 meq/dl at 3 months of age. Normal values for Brahman calves were not identified; however, all serum Fe levels obtained were within the normal values for human serum (40-150 meq/dl). Both Hb and PCV values were within the normal range (10-15 g/100 ml and 36-42%, respectively). A correlation between serum Fe and calf survival was not identified in the present study, however, Mogg (1981) reported that Fe was the only mineral that was significant ($P < .05$) at different ages (at birth and at 3 months of age) and suggested future studies for this relationship (serum Fe and calf survival). Serum Ca concentrations were affected by calf crop with higher values ($P < .01$) in year 1982 than in 1981 (11.2 vs 10.2 mg/100 ml), while P concentrations were higher ($P < .05$) in year 1981 vs 1982 (8.6 vs 8.3 mg/100 ml).

There were no abnormally high or low values ($P > .05$) observed when serum mineral components were evaluated according to treatment, except for Se. Serum Se concentrations were higher ($P < .05$) in treatment 2 and 3 than in treatment 1 (Se supplements vs control). This suggests that dietary mineral concentrations, with exception of Se, in all three groups were adequate to maintain normal serum levels thus masking any effect of dietary treatment.

Blood nitrogenous compounds

Mean analysis of blood metabolic profiles by age are presented in tabla 27 with analysis by calf crop in appandix tabla 61 and analyses by treatment in appendix tabla 62, respectively. All metabolic profile values differed ($P < .01$) among age groups (at birth, 3 days and 3 months of age). There were no abnormally high or low values ($P > .05$) observed when serum mineral components, nursing response, vigor, weight and rectal temperature were evaluated according to dietary treatments. Calf crop x time interactions ($P < .05$) were found for BUN and BUN/creatinine ratio.

Blood urea nitrogen (BUN) is considered an important serum indicator of normal protein metabolism. Franke (1973) reported 11.2 mg/dl to be the normal level for Bos indicus, commenting that weak calves had an approximately equal level of 11.5 mg/dl but showed a much wider range of 6.9 to 16.9 mg/dl. Collins (1978), working with three month old Brahman calves, obtained a SMAC 24 profile mean value of 7.6 mg/dl. Mogg (1981), working with Brahman calves at birth and at 3 days of age, obtained values of 12.0 and 13.6, respectively. In this study, using similar methods of analysis (SMAC 24), the values of 12.7, 13.9 and 10.9 for at birth, 3 days and 3 months of age were obtained for Brahman calves. Mean BUN differed ($P < .001$) among age groups with values reaching a peak (13.9 mg/dl) at 3 days of age and then declining. Preston and Pfander (1963) reported that BUN was a sensitive indicator of protein adequacy and will increase if dietary protein is held constant while energy intake falls.

Values for serum total protein (TP), albumin (Alb) and globulin (Glob) differed ($P < .001$) between age groups. Total protein and

globulin increased with age to a peak at 3 days of age and then started to decline. Comparison values from published data for different ages is difficult since each study dealt with one or two age groups. Most blood metabolic profiles had a consistent trend upward and then downward with increasing age. All samples analyzed for TP were below the normal level of 5.9 g/dl for Brahman calves (Collins, 1978, Mogg, 1981). Plasma protein is extremely sensitive to nutritional influence. Vitamins, growth factors and related substances which affect protein, lipid, and carbohydrate metabolism would consequently be expected to influence the plasma protein profile (Kaneko and Cornelius, 1970a). During protein depletion, tissue proteins are utilized to maintain plasma protein (McAdam and O'Dell, 1982). Collins (1978) reported that Brahman calves had the lowest levels of BUN (7.8 mg/dl) and TP (5.8 g/dl) and the highest concentration of Alb (4.1 mg/dl).

Creatinine is an end product of muscle metabolism which is excreted constantly in urine. A rise in creatinine indicates severe renal damage. Collins (1978) observed mean value of 1.5 mg/dl. Values of 2.3 mg/dl in the present study were reached at birth. This value appears to be abnormal, however, at 3 days and 3 months, these values had decreased to normal levels of 1.8 and 1.25 mg/dl, respectively. This indicates that at birth the renal system may not be functioning at full capacity, hence the buildup of creatinine. Tucker (1978) reported once creatinine is secreted it is not likely to be reabsorbed and must be excreted by the way of the kidney. The wide difference observed for BUN/creatinine ratio is influenced by the sharp depression of creatinine values at 3 days and at 3 months of

age. Creatinine and bilirubin were found to show different serum levels between calf crop groups ($P < .01$) with higher values in year 1981 than in 1982, while BUN/creatinine ratio and uric acid values were higher ($P < .01$) in year 1982 than in 1981

Blood glucose, cholesterol, and lipids

Mean analysis blood glucose, cholesterol, and lipids by age are presented in table 27 with analysis by calf crop in appendix table 61 and analysis by treatment in appendix table 62, respectively. Blood glucose, cholesterol and lipid did not show differences ($P > .05$) among treatment groups, while serum cholesterol and triglyceride concentrations were higher ($P < .05$) for calf crop of 1982 vs 1981 (103 and 20 vs 92 and 13, respectively). Calf crop x time interactions ($P < .01$) were found to affect glucose and cholesterol serum levels.

Glucose is the most important source of energy for newborn calves, thus serum glucose levels represent a strong indicator of calves' energy status. Age ($P < .001$) and calf crop x time interaction ($P < .01$) were both shown to effect glucose level. Mean serum glucose levels were 77, 114, and 93 mg/dl for age groups (at birth, 3 days and 3 months, respectively). Franke (1973) reported 79 mg/dl to be the normal average glucose level for Brahman calves. This work was supported by Collins (1978) who reported a value of 78.8 mg/dl. Franke (1973) suggested that the normal range for serum glucose would be 80-120 mg/dl. In light of this report, all serum glucose values obtained are within the normal range suggested by Franke (1973). However, Mogg (1981) reported higher serum glucose levels for Brahman calves (92 at birth vs 163 mg/dl at 3 days of age

compared to normal value of 79 mg/dl)(Franke, 1973). Collins (1976) reported that yearlings showed the highest values for Angus, 80 mg/dl, and Brahman, 91 mg/dl, alike. This was probably due to diet because the yearling bulls were on concentrate feed containing higher levels of available energy than available in grass and hay consumed by cows.

Age affected ($P < .001$) cholesterol and triglycerides. Mean cholesterol values were 40, 51, and 200 mg/dl for the age groups (at birth, 3 days and 3 months of age). Cholesterol is considered the most important steroid in animal tissue and may be accountable for 90% of the total serum lipids. Triglycerides represent a body fat depot which originates from fatty acids in feed or by synthesis from carbohydrates or amino acids (Maynard and Loosli, 1969). Normal serum triglyceride values for Brahman calves have not been established; however, the values obtained in this study were lower than those reported by Mogg (1981). In the present study, mean serum triglyceride levels were 10, 22, and 17 mg/dl for the three age groups vs 29 and 50 mg/dl for at birth and 3 months of age reported by Mogg (1981).

Blood enzymes

Mean analysis for alkaline phosphatase (ALP), lactic-dehydrogenase (LDH), serum glutamic-oxalacetic transaminase (SGOT), and serum glutamic-pyruvate transaminase (SGPT) by age are presented in table 27, with analysis by calf crop in appendix table 61 and analysis by treatment in appendix table 62, respectively. Blood enzymes were not affected ($P > .05$) by treatment; however, serum ALP and LDH differed ($P < .01$) between calf crop groups. Age ($P < .001$) affected all blood enzymes studied. Serum levels of ALP and SGOT

shewed a steady decrease with increasing age ($P < .001$). The only previous studies available on changing ALP levels with age were those reported by Collins (1975) and Mogg (1981). Calf crop x age interactions also had an affect ($P < .05$) on ALP and SGOT levels. In contrast to ALP and SGOT, SGPT and LDH levels increased ($P < .001$) with increasing age.

Blood enzymes are not tissue specific and their elevation could result due to a number of factors, e.g., tissue abnormalities and damage, age, rate of growth, nutritional factors, system of husbandry. Their usefulness in this study is limited by the above factors and further tests are required to determine specifically which tissues or organs are damaged. Furthermore, sampling problems, low correlation with nutrient intake, and inconsistent pattern in disease make the interpretation more difficult and consequently unacceptable.

Calf Survival and Vigor as Affected by Mineral Supplementation of Their Dams

The relationships examined included vigor, nursing response, rectal temperatures, and birth weights as related to treatment groups (appendix table 67). No differences ($P > .05$) were found in vigor, nursing response, rectal temperature, and birth weight among treatment groups. Franke (1973) observed a definite trend between poor-doing calves and light birth weight. However, in this study, there were light weight calves that were vigorous and nursed as well as heavier calves that were weak and not interested in nursing. The mean birth weights for these calves (appendix table 67) were 32.8, 36.1, and 34.3 kg for the control, added Selenium, and fortified mineral treatment groups, respectively. Mean rectal temperature at birth showed a range from 34.8-38.6° C with all three means falling below 38.9° C (upper

limit). Calves born on cold, wet, and windy mornings or late at night on a whole tended to have problems nursing accompanied by lowered rectal temperature. It was observed that vigor and nursing response were not improved by mineral supplementation of the dams.

Summary

Serum and milk samples were collected for mineral analysis twice (at parturition and 3 months later) in years 1981 and 1982. Blood profile levels of 60 Brahman calves (30 per calf crop) were determined at birth before nursing, 3 days and 3 months of age. Nutritional treatments of dams were examined for relationship to vigor at birth and nursing response. Dams' nutritional treatments were 1) control, 2) added dietary Se plus injectable Se and vitamin E, and 3) control diet with fortified mineral supplement.

Mean cow serum Ca, Mg, P, and PCV values were higher ($P < .05$) at parturition vs three months later, while serum Cu was higher ($P < .05$) at 3 months. Significant calf crop x time interactions ($P < .01$) were found for serum P, Mg, Cu, Zn and Se. Mean serum Ca, Cu and Hb concentrations were affected by duration of experiment, with higher values ($P < .05$) in year 1982 than in 1981. Mean serum Se differed ($P < .001$) among treatments, with higher values in Se and fortified mineral supplement groups. Therefore, tissue concentrations of Se were increased following an increase in dietary Se.

Colostrum was higher ($P < .01$) in Mg, P, Cu, Fe, Se and Zn than in milk (220 vs 61 ug/ml, .13 vs .03%, .49 vs .32 ug/ml, 1.1 vs .51 ug/ml, 0.32 vs .007 ug/ml and 15.4 vs 4.2 ug/ml, respectively), while milk was higher ($P < .01$) than colostrum in Mn (.06 vs .089 ug/ml). Time x treatment interactions ($P < .05$) were found for milk and

colostrum P, Se and Zn, while calf crop x time x treatment interactions were found for P and Se.

Increasing dietary Se resulted in higher ($P < .001$) milk Se concentrations. Means for each treatment x time showed cows fed dietary and dietary plus injectable Se and vitamin E had more ($P < .001$) Se in milk than milk from cows fed no supplemental Se (.020 and .029 ng/ml vs .008 ng/ml, respectively).

Calf serum Ca, Mg, Cu, Se, Na, K, and Cl differed ($P < .001$) among age groups (at birth, 3 days and 3 months of age). There was a tendency for serum mineral composition value to be increased in the profile done at 3 days of age and then start to decline with age. Serum Mg and Se levels decreased by age drastically to values below critical levels. Mean milk concentrations of Mg and Se also decreased from a level of 220 and .032 ug/ml at parturition to 91 and .007 ug/ml in regular milk (3 months after parturition).

Increasing Se intake of cows resulted in higher ($P < .05$) serum Se concentrations in their calves suggesting that Se crosses the placental membrane. However, due to low concentration of Se in milk, calf serum Se values decreased by age from .085 ng/ml at birth to .03 and .016 ng/ml at 3 days and 3 months of age, respectively. At 3 days of age, mean total serum protein was elevated from 4.98 to 5.56 g/dl which was still below the normal level of 5.8 g/dl for Brahman calves (Collins, 1978), reflecting inadequate colostrum intake. At 3 months of age, there was an increase ($P < .001$) in serum Fe from 86 at birth to 167 mg/dl. There was also an increase ($P < .01$) for BUN, BUN/creatinine, glucose, and triglycerides. There was no correlation between dams' diet (mineral supplement) and the occurrence of weak

calves that needed assistance in nursing. Poor calf survival of Brahmans at birth and at 3 days of age is still an unsolved problem to the purebred Brahman breeds. Blood profiles are still complicated by too many factors to be useful as diagnostic tools for evaluating survival rates of newborn Brahman calves.

CHAPTER VII
SUMMARY AND CONCLUSIONS

An experiment was conducted at the University of Florida Pine Acres Beef Research Farm in order to: 1) determine the mineral status of Brahman beef cattle grazing bermudagrass-bahiagrass pastures grown on sandy, well drained soils (Entisols) in central Florida; 2) evaluate animal tissue mineral concentration as affected by mineral supplementation and season of the year; 3) study effect of seasons and locations on the mineral status of soil and forage; 4) evaluate the possibility of correlation between dam's mineral supplementation and calf vigor and nursing response; and 5) compile data of blood profiles for Brahman calves at birth, 3 days and 3 months of age.

In general, soil was acid and low in natural fertility. The experimental units were comprised of 36 Brahman cows (4 to 10 years old) in early pregnancy. Cows were allotted to three treatments of 12 cows each (control, supplemental Se, and fortified mineral supplements). The experimental period (22 months) was divided into 6 collection periods, representing four within the wet (June-October) season and two during the dry (November-May) season. Liver, bone, hair, blood, milk and feces were collected from the 36 cows at the beginning of each period, with exception of bone, feces and milk which were taken only four times. Composite forage and soil samples were collected six times from four pastures where cattle were grazing. Later in the experiment, serum samples were collected from 60 calves (30 per each calf crop) at birth before nursing, 3 days and 3 months

of age.

Milk and serum samples were collected from cows at parturition and 3 months postparturition.

Soil samples were analyzed for Al, Ca, K, Mg, Na, P, Fe, Co, Cu, Mn and Zn. Forage samples were analyzed for the same minerals in the soil in addition to Se but excluding Al. Serum samples were analyzed for Fe, Cu, Ca, P and Mg. Liver was analyzed for Fe, Co, Cu, Mn, Mo and Zn. Bone was analyzed for Ca, P and Mg, specific gravity was determined on air dry bone, whereas bone ash was determined on dry, fat-free bone. Milk was analyzed for Ca, P, Mg, K, Cu, Fe, Mn, Mo, Se and Zn. Feces samples were analyzed for Ca, P, Cu, Zn and Se. Hair samples were analyzed for Mg, Na, K, P, Cu, Fe, Mn, Mo, Se and Zn.

In the initial period (before mineral supplementation), soil, plant, blood serum, and liver tissue concentrations of Ca, K, Na, Mg, Mn and Co were generally adequate. Sixty-nine percent of forages and 40% of serum samples were deficient in P. Seventy-five percent of soils, 38% of forages and 18% of liver samples were deficient in Cu. All samples of forage, liver and serum were deficient in Se. Likewise, all soil and forage samples and 47 and 88% of serum and liver samples, respectively, were deficient in Zn. Mineral elements most likely deficient and needed in supplements for grazing cattle in this region of central Florida are P, Cu, Se and Zn.

Soil analysis for the four locations showed adequate concentrations of Ca, Mg and P during both the wet and dry seasons. However, of all soil samples analyzed for K in the wet and dry season, 69 and 25% were below the critical level of 60 ppm. Extractable soil Ca, K, and P showed seasonal variations with higher ($P < .05$) levels during

the wet than dry season. Forage seasonal differences ($P < .05$) were found for P, Ca, K and Na and were higher in the wet than dry season. Forage P was higher ($P < .05$) during the wet season and, of all forage samples analyzed, 47 and 63% were deficient (< 25%) during the wet and dry seasons, respectively. Of all forage samples analyzed for Mg, Na and K during the wet and dry seasons, 38, 38, 68, 100, 25 and 58%, respectively, were below the critical levels. Crude protein was deficient in both wet and dry seasons. In agreement with low P and Ca concentrations in forage, borderline to deficient concentrations of bone Ca, P, ash, and specific gravity are found in the wet and dry seasons (45 and 51, 93 and 81, 81 and 91, and 41 and 22%, respectively).

Of all samples analyzed, borderline to deficient concentrations of serum Ca (<8) and P (<4 5) were found in the wet and dry season (27 and 15, and 32 and 27%, respectively). Mean fecal P showed seasonal variations, with higher ($P < .05$) levels during the dry vs wet season. The low fecal P in the wet season may be due to increased requirements of animals. Likewise, hair P concentrations were higher in the dry than wet season (248 vs 172 ppm for the wet season). However, hair Mg and Na were higher during the wet than dry season (198, 182 ppm vs 81 and 52 ppm, respectively). Milk Ca and Mg concentrations showed seasonal variations with higher values ($P < .05$) in the wet than dry season (139%, 79 ug/ml vs .124% and 62 ug/ml, respectively). Of the six macro minerals studied, soil K, forage crude protein, P, Na, K and Mg, and animal tissue Ca, P and Mg were most likely to be deficient.

For each soil trace mineral analyzed, no differences ($P > .05$) were found between seasons, however, seasonal differences ($P < .05$)

existed in all forage trace minerals with exception of Cu and Co. Seasonal differences ($P < .05$) were found with liver Co, Cu, Fe, and Mo and serum Fe, higher ($P < .05$) in the wet season and serum Se, fecal Cu, Se, and Zn, and hair Fe, Mn and Se higher in the dry season. Differences among treatments were found for liver, feces and hair Se ($P < .001$) and for serum Fe and Se and fecal Cu and Zn ($P < .05$).

Forage and liver trace mineral analysis showed adequate concentrations of Fe and Mn with no excess of Mo, however, the majority of extractable soil Fe and Mn were below the critical level. In both seasons, extractable soil Co was deficient with forage and liver concentrations within normal levels. Although above critical levels in liver and serum, Cu was low in forage and soil during both seasons. Forage and soil Zn analysis in the wet and dry seasons indicated deficient concentrations, while tissue levels were generally adequate. During the wet season, forage Cu and Zn were low in 85% of samples for both minerals. Extractable Cu, Fe, Mn, Zn, and Co were low in 63, 6%, 100, 88, and 100% of soils, respectively. In the dry season, 100 and 63% of forages were low in Cu and Zn, respectively.

The most pronounced findings from the analysis of samples were the low Se status of pasture soils and animal tissues. In all samples analyzed, Se was deficient in the wet and dry season. On the basis of Se analysis, combined dietary and injectable Se and vitamin E resulted in higher tissue levels. Of the seven trace minerals studied, Cu, Mn, Zn, Co, and Se in soil, Cu, Se and Zn in forages, and Se in animal tissues are most likely to be deficient. Mineral supplementation improved Zn and Se status of animals compared to the initial period. Inadequate Se status observed plus persistent reports of white muscle

disease in the state emphesize the need for increasing dietary inteke of Se

Mean cow serum Ca, Mg, P, and PCV velnes were higher ($P < .05$) at partnrition vs 3 months later, while serum Cu was higher ($P < .05$) at 3 months. Significent calf crop x time interactions ($P < .01$) were found for serum P, Mg, Cn, Zn end Se. Mean serum Ca, Cu, and Hb concentrations were affected by duration of experiment, with higher velnes ($P < .05$) in year 1982 then in 1981. Meen serum Se differed ($P < .001$) among treatments with higher valnes in Se end fortified minerel supplementation groups. Therefore, tissue concentrations of Se were increased following an increese in dietary Se.

Colostrum wes higher ($P < .01$) in Mg, P, Cu, Fe, Se and Zn then milk (220 vs 61 ug/ml, .13 vs .05%, 49 vs .32 ng/ml, 1 1 vs .61 ug/ml, .032 vs .007 ng/ml and 15.4 vs 4.2 ng/ml, respectively) while milk was higher ($P < .01$) in Mn then colostrum (.089 vs .05 ng/ml). Time x treatment interactions ($P < .05$) were found for milk end colostrum P, Se end Zn, while crop x time x treatment interactions were found for P and Se. Increesing dietary Se resulted in higher ($P < .001$) milk Se concentrations vs those fed no supplementel Se.

Calf serum Ca, Mg, Cu, Na, K, and Cl differed ($P < .001$) among age groups (at birth, 3 days and 3 months of ege). There was a tendency for serum minerel composition valne to be increased in the profile done at 3 deys of ege end then start to decline with age. Serum Mg and Se levels decreased by ege dresticelly to velnes below critical levels. Mean milk concentrations of Mg end Se also decreased from a level of 220 end .032 ng/ml et partnrition to 61 and .007 ng/ml in reguler milk (3 months postparturition)

Increasing Se intake of cows resulted in higher ($P < .05$) serum Se concentrations in their calves suggesting that Se crosses the placental membrane. However, due to low concentration of Se in milk, calf serum Se values decreased by age from .086 ug/ml at birth to .03 and .015 ug/ml at 3 days and 3 months of age, respectively. At 3 days of age, mean total serum protein was elevated from 4.68 to 5.59 g/dl which was still below the normal level of 5.9 g/dl for Brahman calves (Collins, 1978), reflecting inadequate colostrum intake. At 3 months of age, there was an increase ($P < .001$) in serum Fe from 86 at birth to 167 mg/dl. There was also an increase ($P < .01$) for BUN, BUN/creatinine, glucose and triglycerides. There was no correlation between dams' diet and the occurrence of weak calves. Poor Brahman calf survival at birth and 3 days of age still remains an unsolved problem for the purebred Brahman breeds. Blood profiles do not appear to be useful diagnostic tools for evaluating survival rate of newborn Brahman calves.

APPENDIX

TABLE 28. SOIL pH AND MACRO MINERAL CONCENTRATIONS AS AFFECTED BY LOCATION (DRY BASIS).

Parameter*	Critical+ level	Locations								Overall mean		Standard error range
		L_1		L_2		L_3		L_4				
		Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	
pH		6.09		5.64		5.95		5.29		5.27		.110-.192
Ca, ppm	71	480[a]	0	338[bc]	0	529[a]	0	358[c]	0	426	0	21.0-22.7
Mg, ppm	9.1	72.7[a]	0	68.7[a]	0	90.0[b]	0	55.3[c]	0	71.5	0	3.01-3.49
Na, ppm		6.33		6.00		5.67		7.67		6.42		.810-.950
K, ppm	60	58.7	43	57.7	63	66.0	43	72.3	43	63.7	48	9.8-16.9
P, ppm	10	62.0[a]	0	58.3[a]	0	73.1[b]	0	118.4[c]	0	78.0	0	2.55-9.86
Al, ppm		180[a]		226[b]		137[a]		309[c]		231		7.2-12.5
O.M., %		1.48[a]		1.77[b]		1.58[a]		1.35[c]		1.70		.027-.041

*LS means are based on the following number of samples: 7 for each of location 1, 2, 3, and 4.

+Critical levels are according to Breland, 1976 (Ca and Mg), Bahia, 1978 (K) and Sanchez, 1976 (P)

a,b,cMeans in the same row with different superscripts differ ($P < .01$)

TABLE 28. FORAGE MACRO ELEMENTS AND PROTEIN CONCENTRATIONS AS AFFECTED BY LOCATIONS (DRY BASIS)

Parameter*	Critical+ level	Locations								Overall mean		Standard error range
		L_1		L_2		L_3		L_4				
		Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	
Ca, %	.30	.375	0	.364	15	.342	31	.380	23	.365	17.3	.001- .013
Mg, %	.20	.252[a]	0	.221[b]	23	.158[c]	38	.107[d]	85	.185	36.5	.361- .325
Na, %	.06	.024	100	.044	65	.026	100	.070	46	.041	82.3	.018- .102
K, %	.60	1.12[a]	15	1.00[a]	38	.92[ab]	38	.66[b]	46	.93	34.3	.050- .123
P, %	.25	.253	38	.234	69	.223	85	.239	54	.237	51.5	.015
Crude protein, %	7	6.01	100	6.13	100	6.00	100	5.90	100	6.01	100	.021- .063

*LS means are based on the following number of samples: 13 for each of location 1, 2, 3, and 4.

+McDowell and Conrad, 1977

Soil and forage samples were collected from the same locations (L_1-L_4) 5 times during the experimental period.

[a,b,c,d]Means in the same row with different superscripts differ ($P < .01$)

TABLE 30. EFFECT OF TREATMENT ON HAIR MACRO ELEMENT CONCENTRATIONS

Parameter[a]	Mineral Supplement T_1	T_2	T_3	S.E.R.[b]
Hair (ppm)				
Mg	182	201	193	13.6-15.0
Na	64	77	71	5.2-6.0
K	107	103	102	6.8-7.6
P	203	198	190	8.1-9.1

[a]LS means are based on the following number of samples: 64, 69, and 65 for treatments 1, 2, and 3, respectively.

[b]Standard error range

The treatments have no significant effect on hair macro elements

TABLE 31 EFFECT OF TREATMENT ON MILK AND COLOSTRUM MACRO MINERAL CONCENTRATIONS

Mineral Supplementation[a]	Ca %	P %	Mg ug/ml	K %
Milk				
T_1	.133	.095	55	.104
T_2	.125	.094	65	.101
T_3	.139	.098	72	.110
S.E. Range[b]	.0030-.0042	.0034-.0037	2.97-3.24	.0045
Colostrum				
T_1	.148	.228	.133	.088
T_2	.143	.228	.133	.100
T_3	.136	.207	.116	.090
S.E. Range[b]	.004	15.5	.001-.004	.004

[a]LS means are based on the following number of samples: milk, 44, 47, and 41, colostrum, 24, 24, and 24 for treatments 1, 2, and 3, respectively.

[b]Standard error range

The treatments, control, control plus Selenium, and fortified minerals (T_1, T_2, and T_3) have no significant effect on the macro minerals of milk and colostrum.

TABLE 32 ANALYSIS OF VARIANCE SUMS OF SQUARES LIVER DATA

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Cobalt	7240	23.9850	14.7240**	2.5680	83.3613
Copper	42384	441690	703875**	56899	1625568
Iron	274901	4047656	5341278**	975353	15805467
Manganese	53.2680	788.3270	884.9610**	130.6510	3615.0430
Molybdenum	.3902	16.2484	47.4354**	8.8079	74.7006
Zinc	143	25935	9290*	5869	101708
Selenium	2.3043**	3.8589	13.7763**	4.6853**	10.5679
df[b]	2	30	5	10	81

[a]Treatment.

[b]Degrees of freedom

*Signficant at the 5% level.

**Significant at the 1% level

TABLE 33. ANALYSIS OF VARIANCE SUMS OF SQUARES BONE DATA.

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Ca	8.9130*	58.8289	244.5399***	13.6789	118.7844
P	7148	21.0778	3.9287	5.2272	42.5707
Mg	.0015	.0482	.1195***	.0054	.1708
Ash	14.945	140.396***	55.300***	29.446	168.461
Ca, % Ash	17.9815	124.4126	488.1579***	16.1526	320.5160
P, % Ash	.5137	36.8171	12.2672**	12.0507	90.6926
Mg, % Ash	.0237	.2822	.2331***	.0961	1.1262
Specific gravity	.01951	1.0932**	.6967***	.1155	1.3089
Ca, mg/cc	370	95872**	183425***	16992	126232
P, mg/cc	63	25497***	9932***	5908**	25774
Mg, mg/cc	1.7261	49.5772	5.7543	18.5066	132.7100
Ca:P ratio	.0159	1.3260	2.5631***	.0729	3.1870
df[b]	2	33	3	6	88

[a]Treatment

[b]Degrees of freedom.

*Signficant at the 5% level.

**Significant at the 1% level.

***Significant at the 1% level.

TABLE 34. ANALYSIS OF VARIANCE SUMS OF SQUARES FOR Hb, PCV AND SERUM FROM CALVES SAMPLED THREE TIMES.

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Calcium	1.6447	28.4799	2.6536	4.5415	49.1783
Magnesium	.3642*	2.0914	4.4613**	.5386	3.9201
Phosphorus	2.6325*	9.6418	5.0027	5.4548	53.4091
Copper	.0421	1.4956*	3.7256**	.1997	1.3953
Zinc	2.7550*	16.0016	8.4046**	6.1107	29.1932
Selenium	.00028	.00183	.00248**	.00034	.00120
Hemoglobin	3.835	51.257	274.409**	9.043	147.166
Hematocrit	8.2058	317.2789	852.2409**	127.6758	1272.8749
df[b]	2	33	2	4	63

[a]Treatment.

[b]Degrees of freedom.

*Signficant at the 5% level.

**Significant at the 1% level.

TABLE 35. ANALYSIS OF VARIANCE SUMS OF SQUARES FOR Hb, PCV AND SERUM FROM COWS SAMPLED SIX TIMES.

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Calcium	5.593	145.667	221.080**	41.154	499.753
Magnesium	.0619	3.7643**	10.4978**	.4458	8.0597
Phosphorus	1.9397	37.4832	93.6933**	20.7536	171.3477
Copper	.0437	.5236	3.5566**	.3523	4.3689
Iron	1.3099	8.8414	26.9768**	1.4088	35.7589
Zinc	.1517	4.6815	14.8340**	1.0994	14.8684
Selenium	.0143*	.0631	.1515**	.0291	.1758
Hemoglobin	4.844	72.592	187.540**	5.550	245.219
Hematocrit (PCV)	164.667*	747.354	1735.301**	265.449	3774.892
df[b]	2	33	5	10	149

[a]Treatment

[b]Degrees of freedom.

*Signficant at the 5% level.

**Significant at the 1% level.

TABLE 38. ANALYSIS OF VARIANCE SUMS OF SQUARES FECES DATA

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Calcium	.2804	2.3954	14.6764***	1.6276*	8.2095
Phosphorus	.0197	.8272	5.0393***	.1942	2.0760
Copper	340**	1028	9362***	437*	2838
Zinc	801*	4283	5929***	1278	9700
Selenium	.0215***	.0275	.0330***	.0095*	.0409
df[b]	2	33	3	6	86

[a]Treatment

[b]Degrees of freedom

*Signficant at the 5% level

**Significant at the 1% level

***Significant at the .1% level.

TABLE 37. ANALYSIS OF VARIANCE SUMS OF SQUARES COLOSTRUM DATA.

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Calcium	.0018	.0150	.0012	.0032	.0155
Magnesium	7211	178813	6309	25133	191633
Potassium	.0019	.01244	.00001	.00053	.01800
Phosphorus	.0046*	.0192	.0425**	.0035*	.0123
Copper	.0860	1.6482	.0153	.0321	1.4536
Iron	2775	2.6379	.0900	.1101	3.1173
Manganese	.00450	.07041	.00005	.00037	.10670
Molybdenum	.00113	.01630	.00004	.00330*	.00018
Zinc	78.614	1033.244	46.401	40.574	711.915
Selenium	.00583**	.01426	.00720**	.00371**	.00720
df[b]	2	33	1	2	33

[a]Treatment

[b]Degrees of freedom.

*Significant at the 5% level.

**Significant at the 1% level

TABLE 38. ANALYSIS OF VARIANCE SUMS OF SQUARES HAIR DATA.

	Sums of Squares				
Response	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Magnesium	13578	351021	981213***	64273	1849097
Sodium	4332	73410	51824***	16738	277497
Potassium	385	143480	281595***	18021	474537
Phosphorus	7187	126733	267794***	11042	659526
Copper	7.937	111.858	80.708***	55.242	690.927
Manganese	4.6	514.2	1436.3***	62.3	3150.3
Iron	5237	89491	698647***	12829	580774
Molybdenum	.0018	.0730	.0676***	.0064	.3736
Selenium	.9781***	.2152	5.4421***	2.4924***	.8149
Zinc	1857	12212	10950***	5310	54154
df[b]	2	33	5	10	140

[a]Treatment.

[b]Degrees of freedom.

*Significant at the 1% level.

TABLE 38. ANALYSIS OF VARIANCE SUMS OF SQUARES MILK DATA

Response	Sums of Squares				
	Treatment	Animal(TRT)[a]	Period	Period*TRT	Residual
Calcium	.0041	0285	.0126**	0017	0607
Magnesium	920	14746	6120**	1620	36696
Potassium	.00155	.02727	.04364**	.00390	.08153
Phosphorus	.00029	.01521	.01127**	.00466	.04681
Copper	.02983	.95424	.46219**	.14010	2 2141
Iron	1 6394	24 0254	53 9448**	3.0736	48 8375
Manganese	.0014	.0882	.1075**	.0271	.2064
Molybdenum	.0025	.0434	.0277**	.0121	.1176
Zinc	11 8513*	35 0664	7.0826	14 7627	132 7830
Selenium	.00044**	00080	.00039*	.00032	.00175
df[b]	2	31	3	6	83

[a]Treatment.

[b]Degrees of freedom.

*Significant at the 1% level.

**Significant at the 1% level.

TABLE 40. ANALYSIS OF VARIANCE SUM'S OF SQUARES SOIL DATA.

	Sums of Squares			
Response	Period	Location	Period*Location	Residual
Calcium	125822*	250832**	376520*	13584
Magnesium	3507*	4138**	7009*	320
Sodium	4486	25	173	24
Potassium	5464	4244	26516	7440
Phosphorus	2480**	15866***	5677*	171
Aluminum	10733*	62568**	10939	1360
Copper	.79***	13.96***	1.14**	.02
Iron	55.51**	957.30***	150.02**	4.00
Manganese	6.277*	20.023***	13.030**	.035
Zinc	.484**	3.989***	2.743**	.031
Cobalt	.00057	.00054	.00093	.00020
Selenium	.00100	.00052	.00380	.0045
pH	1.2509	2.5211	3.1027	.9750
Organic matter	.39857**	.94142***	1.07860**	.02000
df[a]	5	3	15	4

[a]Degrees of freedom.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the .1% level.

TABLE 41 ANALYSIS OF VARIANCE SUMS OF SQUARES FORAGE DATA

	Sums of Squares			
Response	Period	Location	Period*Location	Residual
Calcium	.1097***	.0365***	.3327***	.0430
Magnesium	539***	1507***	93	206
Sodium	.0475*	.0330*	.0361	.1031
Potassium	18.2100***	.92105	1.8601	3.1314
Phosphorus	.2702***	.0164	.0949	.0795
Copper	26185***	10258**	21615	24665
Iron	23067***	1505**	2105	2673
Manganese	2139	26143***	20158***	10508
Molybdenum	22712***	12556***	5293***	730
Selenium	.00265***	.00550***	.00915***	.00260
Zinc	578.2***	1325.3***	1748.4	419.9
Cobalt	.00376	.00306	.01848	.04533
df[a]	5	3	15	28

[a]Degrees of freedom.

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the 1% level.

TABLE 42. COMPARISON OF SOIL AND FORAGE MINERAL CONCENTRATIONS IN THE WET VS DRY SEASON

Parameter	Season[a]		Level of Significance
	Wet	Dry	%
Forage (%)			
Ca	.371	.300	5
Mg	.200	.170	5
Na	.051	.022	5
K	1.09	.60	5
P	.23	.20	NS[b]
N	6.28	5.99	NS
Soil (ppm)			
Ca	437	405	5
Mg	72	71	NS
Na	6.68	6.07	NS
K	80	89	5
P	80	74	5
Al	230	233	NS

[a]Wet season (perios 1, 2, 4 and 5) and dry season (perios 3 and 6).

[b]Nonsignificant.

TABLE 43. MACROELEMENT CONCENTRATIONS OF ANIMAL TISSUES IN THE WET VS DRY SEASON

Parameter	Season[a] Wet	Season[a] Dry	Level of Significance %
Bone (%)			
Ca	24.4	24.3	NS[b]
P	10.3	10.6	NS
Mg	.42	.38	NS
Ash	63.7	64.2	NS
Specific gravity, gm/cc	1.71	1.79	NS
Serum ug/ml)			
Ca, mg/100 ml	9.03	8.40	NS
P, mg/100 ml	5.2	4.8	NS
Mg, mg/100 ml	2.5	2.1	NS
Hb, %	13.1	12.8	NS
PCV, %	39.4	38.7	NS
Feces (%)			
Ca	.89	1.12	5
P	.52	.80	5
Hair (ppm)			
Mg	158	182	5
Na	81	52	5
K	102	108	NS
P	172	248	5
Milk			
Ca, %	.135	.124	5
P, %	.103	.083	5
Mg, ug/ml	72	62	5
K, %	.118	.091	NS

[a]Wet season (perios 1, 2 4 and 6) and dry season (periods 3 and 8)

[b]Nonsignificant.

TABLE 44. SOIL TRACE MINERAL CONCENTRATIONS AS AFFECTED BY LOCATIONS (DRY BASIS).

Parameter[a]	Critical[b] level	Locations 1 Mean	1 % Def	2 Mean	2 % Def	3 Mean	3 % Def	4 Mean	4 % Def	Overall mean Mean	Overall mean % Def	Standard error range
Soil (ppm)												
Cu	.60	.273[c]	100	.210[c]	100	.720[d]	71	2.050[e]	0	.813	58	.025-.621
Fe	19	12.6[c]	100	17.6[d]	71	19.6[e]	57	29.5[f]	0	19.8	57	3.2-5.7
Mn	19	2.53[f]	100	3.28[e]	100	3.86[d]	100	5.09[e]	100	3.76	100	.115-1.62
Zn	2	.843[g]	100	.733[g]	100	.477[h]	100	1.40[i]	43	.863	86	.034-.126
Co	.1	0.252	100	.021	100	.020	100	.031	100	.024	100	.001-.003
Se	.5	.042	100	.040	100	.045	100	.048	100	.044	100	.001-.002

[a]LS means are based on the following number of samples: 7 for each of location 1, 2, 3, and 4. Locations 1, 2 and 3 are exclusively Bahia pasture while location 4 is Bermuda pasture.

[b]Critical levels are according to Horowitz and Oantas, 1973 (Cu), Conrad et al., 1980 (Fe and Mn), Sanchez, 1976 (Zn), Kubota, 1968 (Co), and Cary et al., 1967 (Se).

[c,d,e,f]Means in the same row with different superscripts differ ($P < .001$).

[g,h,i]Means in the same row with different superscripts differ ($P < .01$).

TABLE 45. EFFECT OF LOCATIONS ON TRACE MINERAL COMPOSITION (DRY BASIS) OF FORAGES

Parameter[a]	Critical[b] level	Locations								Overall mean		Standard error range
		L_1		L_2		L_3		L_4				
		Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	Mean	% Def	
Forage (ppm)												
Cu	10	5.61[c]	69	4.32[ef]	69	5.19[d]	100	3.92[f]	77	4.76	78	.065-1.29
Fe	30	56.1[g]	30	63.0[g]	31	72.4[h]	7	61.6[g]	6	63.3	18	.930-2.93
Mo	5	.230[c]	0	.168[de]	0	.145[e]	0	.216[c]	0	.190	0	.010-.030
Mn	30	46.3[i]	15	67.4[ij]	15	55.9[i]	8	103.4[k]	0	68.3	10	1.68-5.82
Se	10	.044[i]	100	.040[i]	100	.021[jk]	100	.028[k]	100	.033	100	.0010-.0028
Zn	30	23.5[i]	92	15.9[j]	100	16.6[k]	100	33.6[l]	31	23.4	58	.163-1.16
Co	.1	.116	15	.136	15	.131	23	.140	15	.131	17	.008-.036

[a]LS means are based on the following number of samples: 13 for each of location 1, 2, 3, and 4, respectively. Locations 1, 2 and 3 are exclusively Bahia pasture while 4 is Bermuda pasture

[b]McDowell and Conrad, 1977.

Forage samples were collected from the 4 locations (L_1-L_4) 6 times during the experimental period.

c,d,e,f,g,h Means in the same row with different superscripts differ ($P < .01$).

i,j,k,l Means in the same row with different superscripts differ ($P < .001$).

TABLE 46. LIVER MINERAL CONCENTRATIONS (DRY BASIS) AS AFFECTED BY TREATMENT.

Parameter*	Critical[+] Level	Mineral Supplementation T_1 Mean	% Def	T_2 Mean	% Def	T_3 Mean	% Def	Standard error range
Liver (ppm)								
Co	.05	78	0	86	0	86	0	13-.15
Cu	75	279	0	282	0	307	0	18-20
Fe	180	558	2	644	0	608	0	58-65
Mn	6	11.5	4	10.7	10	11.7	4	.80-.97
Mo	5	3.0	2	3.2	4	3.0	5	.12-.14
Se	.25	.25[a]	69	.63[b]	27	.64[b]	34	.06-.17
Zn	84	102	13	99	11	101	9	4.7-5.1

*LS means are based on the following number of samples: 55, 57, and 54 except for Selenium (42, 44, and 43) for treatment 1, 2, and 3, respectively.

[+]McDowell, 1976. McDowell and Conrad, 1977

T_1, T_2, and T_3 are control, control plus Selenium and fortified mineral supplements, respectively.

[a,b]Means in the same row with different superscripts differ ($P < .001$)

TABLE 47 EFFECT OF TREATMENT ON HAIR TRACE MINERAL CONCENTRATION

Parameter[a]	Mineral Supplementation T_1	T_2	T_3	S.E.R.[b]
Hair (ppm)				
Cu	5.78	6.74	7.10	.24-.27
Fe	133	141	130	7.6-8.5
Mn	7.74	7.98	8.16	.56-.62
Mo	.177	.115	.109	.006-.009
Se	.115[c]	.282[d]	.245[d]	.011-.013
Zn	82	89	87	2.3-2.8

[a]LS means are based on the following number of samples: 64, 69, and 65 except for Se (56, 64, and 52) for treatments 1, 2, and 3, respectively

[b]Standard error range

T_1, T_2, T_3 are control, control plus Selenium, and fortified mineral supplement, respectively

[c,d]Means in the same row with different superscripts differ ($P < .001$).

TABLE 48 EFFECT OF TREATMENT ON MILK AND COLOSTRUM TRACE MINERAL CONCENTRATIONS

Mineral Supplementation	Cu	Fe	Mn	Mo	Se	Zn
Milk (ug/ml)*						
T_1	.344	.893	.084	.028	.0046[e]	4.14[ab]
T_2	.347	.988	.082	.034	.0097[d]	3.75[a]
T_3	.315	1.204	.091	.040	.0062[e]	4.51[b]
S.E. Range+	.023- .025	.10- .12	.007	.005	.0008- .0010	.17- .19
Colostrum (ug/ml)						
T_1	.471	1.124	.067	.036	.0148[f]	15.75
T_2	.455	.887	.043	.038	.049[d]	16.40
T_3	.540	.959	.054	.029	.031[e]	13.93
S.E. Range+	.043	.063	.012	.0044	.003- .005	.948

*LS Means are based on the following number of samples: milk, 44, 47, and 41, colostrum, 24, 24, and 24 for treatments 1, 3, and 3, respectively

+Standard error range

T_1, T_2, and T_3 are control, control plus Selenium and fortified mineral supplements, respectively.

a,b Means in the same column with different superscripts differ ($P < .05$).

d,e,f Means in the same column with different superscripts differ ($P < .05$).

TABLE 48. COMPARISON OF SOIL AND FORAGE MINERAL CONCENTRATIONS IN THE WET VS DRY SEASON

Parameter	Season[a] Wet	Season[a] Dry	Level of Significance %
Forage (ppm)			
Cu	4.38	4.84	NS[b]
Fe	55.0	79.9	1
Mo	.202	.179	5
Mn	66.4	71.0	5
Se	.037	.026	6
Zn	21.3	27.6	6
Co	.125	.144	5
Soil (ppm)			
Cu	.836	.770	NS
Fe	18.7	20.5	NS
Mn	3.86	3.59	NS
Zn	.832	.810	NS
Co	.024	.026	NS
Se	.042	.046	NS

[a]Wet season (periods 1, 2 4 and 5) and dry season (periods 3 and 6).

[b]Nonsignificant

TABLE 50. TRACE MINERAL CONCENTRATIONS OF ANIMAL TISSUES IN THE WET VS DRY SEASON

Parameter	Season[a] Wet	Season[a] Dry	Level of Significance %
Liver (ppm)			
Co	.63	.43	1
Cu	317	290	1
Fe	553	548	5
Mn	11.5	10.5	NS[b]
Mo	3.43	2.76	5
Se	.338	.335	NS
Zn	103	95	NS
Serum (ug/ml)			
Cu	1.08	.98	NS
Fe	1.79	1.27	5
Se	.021	.084	1
Zn	1.31	1.18	NS
Feces (ppm)			
Cu	12.0	24.3	1
Se	.045	.080	1
Zn	55.2	67.0	5
Hair (ppm)			
Cu	6.75	7.12	NS
Fe	104	136	5
Mn	7.26	9.36	5
Mo	.105	.123	NS
Se	.125	.403	.1
Zn	85	87	NS
Milk (ug/ml)			
Cu	.35	.33	NS
Fe	.81	.73	5
Mn	.035	.080	5
Mo	.025	.044	5
Se	.005	.009	1
Zn	4.33	3.90	NS

[a]Wet season (series 1, 2 4 and 5) and dry season (periods 3 and 6)

[b]Nonsignificant.

TABLE 51. FORAGE GROSS CORRELATION COEFFICIENTS

Response*	Ca	Cu	Fe	Mg	Mo	Mn	Na	K	P	Se	Zn	Co
Copper	.265[a]											
Iron	.103	-.512[d]										
Magnesium	.285[a]	.443[c]	-.215									
Molybdenum	.320[b]	-.334[c]	.365[c]	-.156								
Manganese	.469[d]	.110	.067	-.168	.166							
Sodium	.085	.070	-.296[b]	.038	-.210	.502[d]						
Potassium	-.014	.446[c]	-.283[a]	.399[c]	-.301[b]	.155	.484[d]					
Phosphorus	.376[b]	.137	-.138	.460[d]	-.038	.317[b]	.481[d]	.354[b]				
Selenium	.196	.373[b]	-.008	.365[b]	.147	.179	-.065	.308[b]	-.038			
Zinc	.448[c]	-.051	.219	-.160	.452[c]	.637[d]	.180	.024	.284[a]	.045		
Cobalt	.052	-.057	.237	.118	.073	.213	-.022	.027	.292[b]	.087	.246	1.0000

*Critical values of the correlation coefficients are .265, .292, .365, and .469 for P = .05, .01, .001 and .0001, respectively.

[a]Significant at the 5% level.

[b]Significant at the 1% level.

[c,d]Significant at the .1% level.

TABLE 52. SOIL GROSS CORRELATION COEFFICIENTS

Response*	Ca	Mg	Na	K	P	Al	Cu	Fe	Mn	Zn	Co	Se	pH
Magnesium	.818[d]												
Sodium	-.305	-.364											
Potassium	.096	.158	.205										
Phosphorus	.285	.073	-.111	.380[a]									
Aluminum	.209	.106	.257	.350	.763[d]								
Copper	-.139	-.213	.206	.118	.767[d]	.745[d]							
Iron	-.358	-.352	.205	.029	.592[c]	.689[d]	.874[d]						
Manganese	.132	.122	.197	.337	.738[d]	.659[d]	.636[c]	.655*					
Zinc	-.142	-.182	.316	.488[b]	.604[c]	.619[c]	.505[b]	.379[a]	.627[c]				
Cobalt	-.149	-.170	.350	.186	.348	.458[b]	.411[a]	.286	.334	.524[c]			
Selenium	-.222	-.193	.327	.195	.196	.199	.282	.321	.041	.137	.456[b]		
pH	.557[c]	.593[c]	-.143	.165	-.232	-.560[c]	-.441[b]	-.560[c]	-.305	-.256	-.459[b]	-.218	1.000

*Critical values of the correlation coefficients are .380, .441, .524 and .659 for P = .05, .01, .001 and .0001, respectively

The sample size for soil is 28.

[a]Significant at the 5% level.

[b]Significant at the 1% level.

[c,d]Significant at the .1% level.

TABLE 53 GROSS CORRELATION COEFFICIENTS IN ANIMAL TISSUES

	Liver						Serum					Bone (Fat free basis)				
Responses[a]	Cu	Zn	Fe	Mn	Co	Mo	Cu	Zn	P	Ca	Mg	Ash	P	Co	Ca : P	Mg
Liver																
Cu	1 000															
Zn	301*	1 000														
Fe	128	213	1 000													
Mn	216*	260*	056	1 000												
Co	253*	258*	103	291	1 000											
Mo	086	311**	389**	286*	103	1 000										
Serum																
Cu	101	083	012	111	101	186**	1 000									
Zn	110	078	193	111	060	200	013	1 000								
P	132	103	119	046	126	151	311**	023	1 000							
Ca	129	259*	019	123	118	131	073	011	019	1 000						
Mg	028	280*	001	060	095	121	003	031	018	023**						
Bone																
Ash	031	009	121	059	003	041	084	112	026	391**	146	1 000				
P	001	034	011	010	100	015	635	100	043	051	000	022	1 000			
Co	026	082	031	111	123	046	008	011	123	071	041	331**	401**	1 000		
Ca : P	019	011	061	041	018	001	099	101	206	005	065	209	531**	411**	1 000	
Mg	112	081	001	254*	001	307**	010	064	081	000	061	111	338**	416**	053	1 000

[a] Sample size for liver serum and bone is 109 207 and 216 respectively

* Significant at the 5% level

** Significant at the 1% level

TABLE 54 GROSS CORRELATION COEFFICIENTS BETWEEN ANIMAL TISSUE AND FORAGE PARAMETERS.

Animal Tissue Parameter	Forage Parameter	Correlation Coefficient
Serum		
Ca	Cu	.544**
Mg	Cu	.446*
Feces		
Ca	Zn	.375*
P	Na	.531**
Zn	Zn	.534**
Zn	Mg	-.428*
Cu	Zn	.400*
Co	Na	.343*
Hair		
P	P	- 509**
P	Mg	- 518**
P	K	-.575**
Zn	Mg	-.544**
Zn	K	- 614**
Cu	Mg	- 427*
Cu	K	- 507**
Mn	Mg	- 348*
Mn	Cu	- 387*
Mn	Mn	503**
Se	Fe	398*
Se	Cu	- 428*

TABLE 64-continued

Animal Tissue Parameter	Forage Parameter	Correlation Coefficient
Zn	Mo	.426*
Liver		
Fe	K	-.449*
Cu	Zn	.517**
Mn	Mg	- 398*
Mo	Se	.418*

*Significant at the 5% level

**Significant at the 1% level

TABLE 55. HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM MINERAL COMPOSITION OF COWS AS AFFECTED BY DURATION OF MINERAL SUPPLEMENTATION.

Year[a]	Ca mg/100 ml	Mg mg/100 ml	P mg/100 ml	Cu ug/ml	Zn ug/ml	Se ug/ml	Hb %	PCV %
1981[b]	7.80[d]	2.43	4.71	1.04[d]	1.41	.051	12.1[d]	36.6
1982	9.60[e]	2.56	4.48	.99[e]	1.43	.070	14.0[e]	38.4
S.E.R.[c]	.17-.18	.049-.048	.161	.026-.027	.002	.003	.148-.155	.42-.44

[a]LS means are based on the following number of samples: 70 and 66 for years 1981 and 1982, respectively.

[b]Brahman cows were sampled twice in years 1981 and 1982.

[c]Standard error range.

[d,e]Means in the same column with different superscripts differ ($P < .01$).

TABLE 56. EEEECT OF TREATMENTS ON HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM MINERAL COMPOSITION OE COWS COLLECTED TWICE, IN YEAR 1981 AND 1982.

Mineral[a] Supplmentation	Ca mg/100 ml	Mg mg/100 ml	P mg/100 ml	Cu ug/ml	Zn ug/ml	Se ug/ml	Hb %	PCV %
T_1	8 65	2 46	4 56	978	4 01	026[c]	13 8[e]	36 2
T_2	8 57	2 51	4 51	1 08	4 32	090[d]	13 1[ef]	37 7
T_3	8 88	2 52	4 72	1 06	4 60	0 69[d]	12 6[df]	36 0
S E.M.[b]	.217- 228	.058-.061	.193- 202	.032-.034	.110-.123	.009-.010	.183- 191	.523-.696

[a]LS means are based on the following number of samples: 40, 47 and 45 for treatments 1, 2, and 3, respectively.

[b]Standard error range

T_1, T_2, and T_3 are control, control plus Se and fortified mineral supplements, respectively.

[c,d]Means in the same column with different superscripts differ (P < .001)

[e,f]Means in the same column with different superscripts differ (P < .05)

TABLE 57. EFFECT OF TREATMENT ON MILK MINERAL CONCENTRATIONS (COLLECTED TWICE IN 1981 AND 1982).

Mineral[a] Supplementation	Ca %	Mg ug/ml	K %	P %	Cu ug/ml	Fe ug/ml	Mn ug/ml	Mo ug/ml	Se ug/ml	Zn ug/ml
T_1	140	142	092	111	406	951[c]	075	030	009[e]	9 78
T_2	132	144	097	110	394	757[cd]	067	040	029[f]	10.2
T_3	132	136	095	104	419	705[d]	082	038	020[g]	8.42
S.E.M.[b]	.0032	7.85-8.50	.002-.0032	.0023	.028-.031	.042-.046	.007-.008	.005-.006	.002-.003	511-535

[a]LS means are based on the following number of samples: 46, 48, and 44 for treatments 1, 2, and 3, respectively.

[b]Standard error range.

T_1, T_2, and T_3 are control, control plus Selenium and fortified mineral supplements, respectively.

[c,d]Means in the same column with different superscripts differ ($P < .05$).

[e,f,g]Means in the same column with different superscripts differ ($P < .05$).

TABLE 58. MILK MINERAL COMPOSITION AS AFFECTED BY DURATION OF THE EXPERIMENT.

Year[a]	Ca %	Mg ug/ml	K %	P %	Cu ug/ml	Fe ug/ml	Mn ug/ml	Mo ng/ml	Se ug/ml	Zn ug/ml
1981[b]	134	136	.087	.102	.392	.752	.064	.025[d]	.025[d]	9.52
1982	136	147	.092	.115	.416	.789	.085	.049[e]	.015[e]	10.00
S.E.R.[c]	.0026	6.55-5.72	.002	.0019	.023-.024	.035-.037	.0061-.0063	.004-.005	.0019	.422-.427

[a]LS means are based on the following number of samples: 72 and 66 for years 1981 and 1982, respectively.

[b]Milk was collected twice in years 1981 and 1982.

[c]Standard error range.

[d,e]Means in the same column with different superscripts differ ($P < .001$).

TABLE 59. EFFECT OF CALF CROP ON HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM MINERAL CONCENTRATIONS

Parameter[a]	Calf Crop[b] 1981	Calf Crop[b] 1982	Standard error range
Ca, mg/100 ml	10.2[d]	11.2[c]	.106-.170
P, mg/100 ml	8.6[c]	8.3[d]	.015-.126
Mg, mg/100 ml	2.29	2.27	.006-.036
Cu, ug/ml	.621	.634	.003-.020
Zn, ug/ml	1.15	1.32	.008-.013
Se, ug/ml	.040	.048	.001-.006
Hb, %	12.6	13.0	.214-.220
PCV, %	42.0	41.3	.704-.721

[a]LS means are based on the following number of samples: 90 and 89 for calf crop 1981 and 1982, respectively.

[b]Both 1981 and 1982 calf crops were sampled three times.

[c,d]Means in the same row with different superscripts differ ($P < .05$).

TABLE 60. HEMOGLOBIN (Hb), PACK CELL VOLUME (PCV), AND SERUM MINERAL CONCENTRATIONS OF CALVES AS AFFECTED BY MINERAL SUPPLEMENTATION OF THEIR DAMS.

Parameter[a]	Treatment[b] T_1	T_2	T_3	Standard error range
Ca, mg/100 ml	10.5	11.2	10.2	.181-.208
P, mg/100 ml	6.3	6.3	6.6	.148-.153
Mg, mg/100 ml	2.28	2.34	2.22	.042-.044
Cu, ug/ml	.602	.628	.653	.022-.024
Zn, ug/ml	1.18	1.19	1.15	.008-.010
Se, ug/ml	.030[c]	.053[d]	.049[d]	.005-.006
Hb, %	13.1	12.8	12.4	.263-.270
PCV, %	42.7	41.2	41.0	.862-.884

[a] LS means are based on the following number of samples: 59, 60, and 56 for treatments 1, 2, and 3, respectively.

[b] T_1, T_2, and T_3 stand for control, control plus Selenium and fortified mineral supplements, respectively.

[c,d] Means in the same row with different superscripts differ.

Mineral supplementation of the dams has no significant effect ($P < .05$) on Hb, PCV and serum mineral concentrations of their calves except for Se which is higher ($P < .06$) in treatments 2 and 3 vs 1.

TABLE 61. BLOOD METABOLIC PROFILES AS AFFECTED BY CALF CROP (YEARS 1981 AND 1982).

Parameter[a]	Calf crop[b] 1981	1982	Standard error range
Glucose, mg/dl	93.8	95.2	3.47-3.78
Na, meq/l	140.5	139.1	.760-.829
K, meq/l	4.97	5.06	.048-.053
Chloride, meq/l	101.3	100.0	.546-.595
CO_2 content, meq/l	19.7	19.7	.241-.263
Na-(Cl+CO_2), meq/l	19.2	19.8	.233-.254
BUN[g], mg/dl	12.1	12.9	.350-.382
Creatinine, mg/dl	1.89[c]	1.53[d]	.059-.064
BUN/Creatinine ratio	7.02[d]	9.95[c]	.296-.321
Uric acid, mg/dl	.857[k]	1.050[j]	.058-.063
Total protein, g/dl	5.14	5.20	.092-.100
Albumin, g/dl	3.14	3.22	.053-.058
Globulin, g/dl	1.99	2.04	.097-.105
A/G[h] ratio	1.59	1.79	.066-.072
Ionized Ca, mg/dl	4.61[d]	5.36[c]	.096-.103
Bilirubin, total, mg/dl	.622[j]	.441[k]	.045-.046
Alkaline phosphatase, U/l	685[j]	422[k]	60.3-65.7
LDH[i], U/l	750[k]	878[j]	18.8-21.6
SGOT[j], U/l	45.5	40.6	2.39-2.60
SGPT[k], U/l	20.4	19.8	1.13-1.24
Cholesterol, total, mg/dl	91.8[m]	103.0[l]	3.31-3.60
Triglycerides, mg/dl	13.3[d]	20.1[c]	1.16-1.26
Fe, Serum, ug/dl	108[k]	133[j]	6.71-7.31

TABLE 61-continued.

[e]LS means are based on the following number of samples 80 and 88 for years 1981 and 1982, respectively

[b]Both 1981 and 1982 calf crops were sampled three times.

[c,d]Means in the same row with different superscripts differ ($P < .001$)

[e]Blood urea nitrogen

[f]Albumin/globulin ratio.

[g]Lactic dehydrogenase.

[h]Serum glutamic-oxelecetic transaminase.

[i]Serum glutamic-pyruvate transaminase.

[j,k]Means in the same row with different superscripts differ ($P < .01$)

[l,m]Means in the same row with different superscripts differ ($P < .05$)

TABLE 62. BLOOD METABOLIC PROFILES OF CALVES AS AFFECTED BY MINERAL SUPPLEMENTATIONS OF THEIR DAMS[a]

Parameter[a]	Treatment[b] T_1	T_2	T_3	Standard error range
Glucose, mg/dl	99.0	95.1	89.3	4.35-4.74
Na, meq/l	140	141	139	.953-1.04
K, meq/l	5.01	5.12	4.51	.060-.066
Chloride, meq/l	99.5	102.0	100.0	.685-.747
CO_2 content, meq/l	20.1	19.3	19.8	.302-.329
Na (Cl + CO_2), meq/l	19.6	19.4	19.4	.293-.319
BUN[f], mg/dl	12.4	12.7	12.3	.430-.479
Creatinine, mg/dl	1.68	1.75	1.71	.074-.081
BUN/Creatinine ratio	8.51	8.45	8.44	.370-.403
Uric acid, mg/dl	.987	.913	.975	.072-.078
Total protein, g/dl	5.32	5.09	5.10	.116-.127
Albumin, g/dl	3.12	3.17	3.24	.066-.072
Globulin, g/dl	2.20	1.91	1.92	.121-.131
A/G[g] ratio	1.68	1.91	1.93	.063-.069
Ionized Ca, mg/dl	4.95	4.93	5.07	.119-.130
Bilirubin, total, mg/dl	.445	.648	.600	.056-.061
Alkaline phosphatase, U/l	534	530	539	76.6-82.4
LDH[h], U/l	799	783	785	24.8-27.0
SGOT[i], U/l	42.0	41.5	45.6	2.93-3.26
SGPT[j], U/l	20.2	20.1	20.1	1.42-1.55
Cholesterol, total, mg/dl	106.0[c]	97.0[cd]	88.6[d]	4.15-4.52
Triglycerides, mg/dl	17.7	17.6	14.8	1.45-1.58
Fe, serum, ug/dl	121	121	116	8.41-9.17

TABLE 52-continued.

[a]LS means are based on the following number of samples: 57, 57, and 54 for treatment 1, 2, and 3, respectively.

[b]T_1, T_2, and T_3 stand for control, control plus Selenium and fortified mineral supplements, respectively.

[c,d,e]Means in the same row with different superscripts differ ($P < .05$).

[f]Blood urea nitrogen

[g]Albumin/globulin ratio

[h]Lactic dehydrogenase

[i]Serum glutamic-oxalacetic transaminase

[j]Serum glutamic-pyruvate transaminase

TABLE 63 ANALYSIS OF VARIANCE SUM OF SQUARES CALF BLOOD PROFILES DATA

Response	Crop	Treatment	Crop*Trt	Animal[TRT]	Time	Crop*Time	Time*Trt	Crop*Time *Trt	Residual
Glucose	56	1376	1048	13737	40306***	6792**	2593	1676	129833
Sodium	90.33	83 28	333 60	2236 01*	2830 00****	89 76	209 51	116 63	6180 06
Potassium	2000	1 0053	2434	6 6000	12 0001***	2 3240**	1 8013	5645	26 1206
Chloride	89 62	195 71	77 62	680 63	690 88***	11 16	189 33	73 10	3280 62
CO_2 Content	01	16 33	6 00	205 61	662 81***	6 82	72 31**	28 61	623 32
Balance	16 13	1 06	9 16	201 32*	66 73**	68 54	32 46	16 61	582 62
Blood urea nitrogen	24 26	0 17	1 01	283 01	257 62***	61 66*	22 26	92	1316 67
Creatinine	4 486***	230	016	0 536	29 080***	13 857***	890	1 176	37 627
BUN/Creatinine	107 6**	2 0	2 9	193 6	670 6***	166 1***	5 9	33 6	931 3
Uric acid	1 101	150	163	7 587	7 632**^	3 329**	1 023	2 037	35 300
Total protein	0709	1 7810	0076	18 0733	26 5803***^	3 8233	1.6214	5484	91 9259
Albumin	2258	5317	1 3953	5 8936	3 84204**^	0110	1 6373	5736	29 6263
Globulin	0061	2 6963	1327	10 2184	20 5803***^	2 7060	6066	1 2583	99 4305
A/G ratio	3865	2 8493	6325	10 0307	10 0106***^	3 7550**^	8048	4386	41 3529
Ionized Ca	21 36**	16	1 03	16 96	40 61***	11 80**^	6 66	5 71	96 39
Bilirubin total	1 3510	6502	1988	3 23	11 2829**^	1 3678**^	1 2984	1637	23 3427
Alkaline phosphatase	2503636	25086	645295	6008569	6112599***	2308351*	1347356	354368	28930552

LDH	221756	6306	20776	1181714	381157.5***	464366***	183054	105447	4196726
SGOT	832	872	1152	3332	10232***	1054	3514	1367	61074
SGPT	6	47	604	4436	4893***	386	847	411	13740
Cholesterol_total	4430*	7030*	505	27947	907526***	2070	15034**	430	112186
triglycerides	1630*	153	183	3094	4515***	2893***	1110	398	14404
ie serum	20867**	1760	293	62645	145456***	24523*	4539	5242	402205
al	1	2	2	27	2	2	4	4	123

*Significant at the 5% level

**Significant at the 1% level

***Significant at the .1% level

TABLE 44 ANALYSIS OF VARIANCE SUMS OF SQUARES CALF (2) HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM DATA.

Response	Crop	Treatment	Crop*TRT	Animal(TRT)	Time	Crop*Time	Time*TRT	Crop*Time *TRT	Rest(Error)
Calcium	51 52*	95 23	2 76	121.8**	855 33***	97 06***	11 72	6 33	349 74
Phosphorus	5 44*	10 27	.47	60 33*	0 32	14 87**	0 60	54	199 84
Magnesium	0160	4304	.6082	6 021**	15 488E***	.0623	1 4083**	.8103	15 9670
Copper	0080	0775	.0078	1 546	5 7635***	0674	.1956	.0244	4 6343
Zinc	0310	8400	.0681*	12 142*	30 0684***	0845	2.0165**	1.8204*	32.3850
Selenium	0029*	0173*	.0003	0063	.1608***	0551*	0163*	0005	3601
Hemoglobin	6 92	21 59	T 87	212 60**	36 00**	20 22	19 29	1 88	568 25
Hematocrit (PCV)	24 10	T19 01	28 28	2356 05**	172.06	3 33	149 51	48.88	5891 86
Df	T	2	2	27	2	2	4	4	135

*Significant at the 5% level

**Significant at the 1% level

***Significant at the .1% level

TABLE 65 ANALYSIS OF VARIANCE SUMS OF SQUARES COW (2) HEMOGLOBIN (Hb), PACKED CELL VOLUME (PCV) AND SERUM DATA

Response	Crop	Treatment	Crop*TRT	Animal(TRT)	Time	Crop*Time	Time*TRT	Crop*Time *TRT	Residual
Calcium	113 8*	1 2	6 4	61 6	5008 5**	5 9	2 1	3 3	207 3
Magnesium	6197	0664	2812	3 1948	1 3248**	1 1818***	1618	0835	15 098
Phosphorus	2 321	1 131	1 116	61 700	29 138***	17 162***	768	329	161 962
Copper	3465**	2952	0218	2 1538	7736***	1 2760***	0192	0423	4 6900
Zinc	6823**	5852*	0434	4 3831*	1 4413**	2 5420***	0562	0848	8 8868
Selenium	0046*	0191**	0024*	0742	0001*	0034***	0006	0256*	1971
Hemoglobin	329 7**	18 7*	2 4	88 1	6 8*	1	6 6	1 2	138 1
Immature RBC (PCV)	110 4	34 0	24 9	256 6	196 1***	5	16 8	29 9	2117 9
df	1	2	2	33	1	1	2	2	99

*Significant at the 5% level

**Significant at the 1% level

***Significant at the 1% level

TABLE 56. ANALYSIS OF VARIANCE SUMS OF SQUARES MILK DATA COLLECTED AT PARTURITION AND 3 MONTHS LATER.

Response	Crop	Treatment	Crop*TRT	Animal(TRT)	Time	Crop*Time	Time*TRT	Crop*Time *TRT	Residual
Calcium	0002	0019*	0011	0190*	0029***	0011	0012*	0023*	0436
Magnesium	4345	2849	16883	113585	045582***	1858	7819	9340	225334
Potassium	.00052	00065	00032	.01429	.00058	00030	00164	00258	03963
Phosphorus	00039	00220	00120	.01923***	.04549***	04872***	.00285**	.00122*	.12422
Copper	01622	01097	00267	00243	1 01250***	09843	10292	04207	3 53283
Iron	0352*	3822	0030	T 9228	8 2938***	3224*	0926	T772	2 8224
Manganese	0124	0849	0056	.0065	.0252***	0151**	.0030	0125*	.2428
Molybdenum	0128*	0017	0018	0052	0016	0066*	0045	0056	1394
Selenium	0034	0056***	0013*	0022	0185***	0042***	.0036***	0023**	0148
Zinc	TT 35	32 02	12 T3	588.10	4352 91***	39 26*	22.48*	23 78	1267.21
df	T	2	2	33	1	T	2	2	93

*Significant at the 5% level.

**Significant at the 1% level

***Significant at the .1% level

TABLE 67. EFFECT OF TREATMENT ON VIGOR, NURSING RESPONSE, BIRTH WEIGHT AND RECTAL TEMPERATURE.

Treatment[a]	Vigor Score	Nursing Response	Birth Weight (kg)	Rectal Temperature
T_1[b]	1.8	1.9	32.8	33.0
T_2	1.6	1.8	35.1	36.6
T_3	2.0	1.8	34.3	39.0
S.E.R.[c]	.01-.18	.010-.013	1.01-3.01	.95-2.61

[a]LS Means are based on 20 samples per each treatment

[b]T_1 stands for control, while T_2 high in Se and T_3 fortified mineral supplement.

[c]Standard error range.

Treatment has no significant effect on vigor, nursing response and rectal temperature.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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